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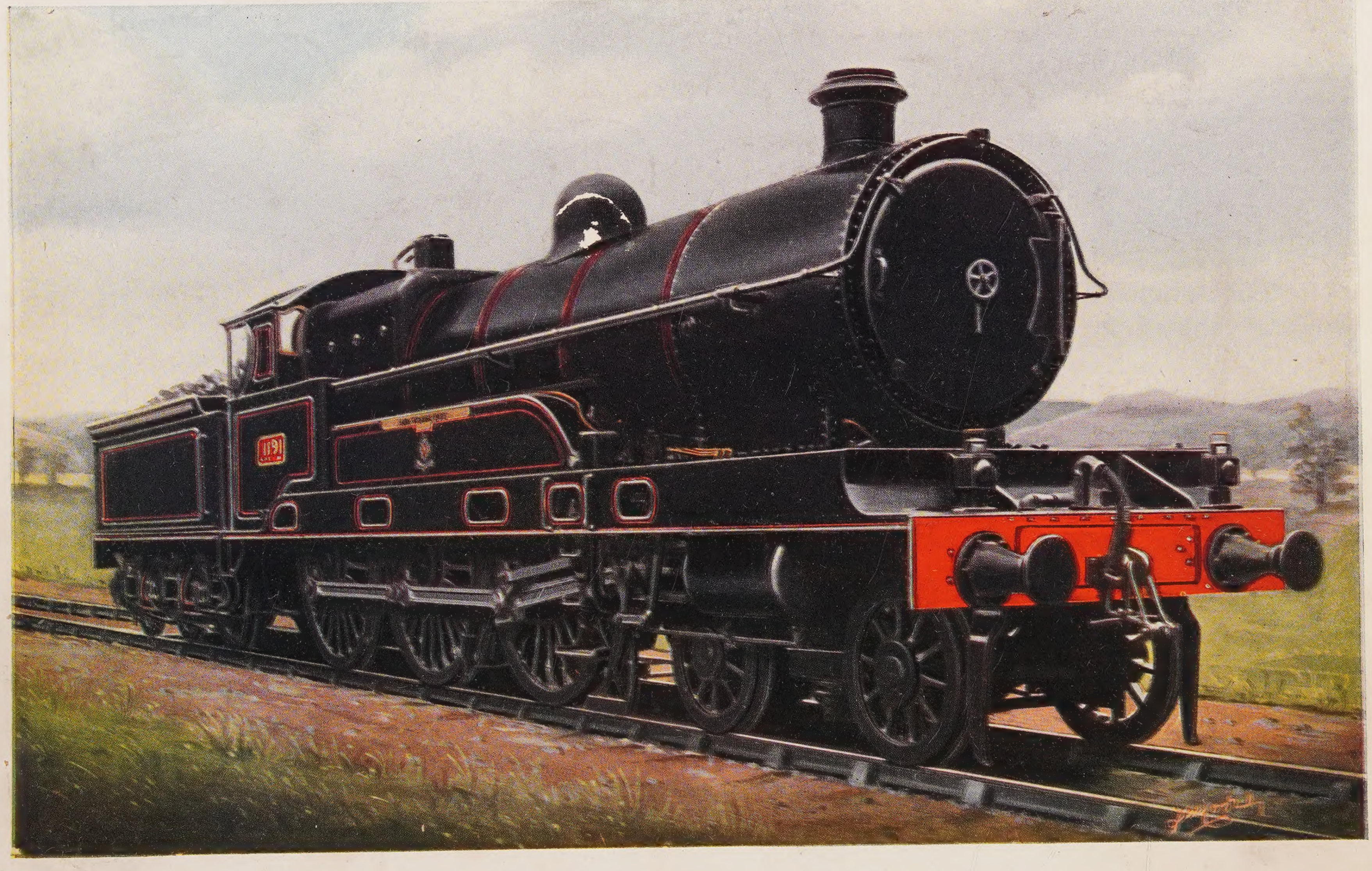

Over Shap Summit : A North Western " Claughton."

LOCOMOTIVES OF THE WORLD

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BY THE

REV. J. R. HOWDEN, B.D.

AUTHOR OF
"THE BOY'S BOOK OF LOCOMOTIVES," ETC.

NEW AND REVISED EDITION

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PREFACE

SINCE the first edition of *Locomotives of the World* appeared, and indeed while the present edition has been in the press, a great change has been carried through in the management of the Railways of Great Britain. This has been brought about by the action of the Government, and consists in nothing less than the gathering together into four big groups of all the railways in the country. The history of British lines—and the same is true of every other country where the railway has been long at work—has been a more or less continuous record of amalgamations, smaller companies combining together in various ways to form larger ones. Of late years, too, we have seen in North America the growth of immense railroad systems, operating in some cases tens of thousands of miles of track. The economic advantages to be looked for from this policy have influenced the authorities in Great Britain to bring about a similar rearrangement of the lines. The whole of the railways in England, Scotland and Wales will soon be comprised within the aforementioned groups. Indeed, it is quite likely that it will have been accomplished by the time the present volume appears in print. The groups will be composed as follows :—

I. The Great Western system will include :
    1. The old Great Western.
    2. Cambrian.
    3. Brecon and Merthyr.
    4. Taff Vale.
    5. Barry.
    6. Burry Port and Gwendreath Valley.
    7. Cardiff.
    8. Cleobury Mortimer and Ditton Priors.
    9. Neath and Brecon.
    10. Port Talbot Railway and Docks.
    11. Rhondda and Swansea Bay.
    12. Rhymney.
    13. South Wales Mineral.

II. The Southern Railway system will include:

1. London and South-Western.
2. London, Brighton and South Coast.
3. South-Eastern and Chatham.
4. Isle of Wight Central.

III. The London, Midland and Scottish system will include:

1. London and North-Western.
2. Lancashire and Yorkshire.
3. Midland.
4. Furness.
5. North Staffordshire.
6. Caledonian.
7. Glasgow and South-Western.
8. Highland.

IV. The London and North-Eastern Group will include:

1. Great Northern.
2. Great Central.
3. Great Eastern.
4. North-Eastern.
5. North British.
6. Great North of Scotland.
7. Hull and Barnsley.

What changes will ultimately be brought about in the locomotive stocks of the various lines remain yet to seen. The only approach to unification of design which has become apparent so far is that certain experiments in painting have been carried out in the case of some of the companies involved. The first outward and visible sign I have come across which in any way suggested the change was that in February of this year (1923) I saw a Midland goods-engine hauling a coal train on the London and North-Western main line near Rugby. It will be interesting to locomotive lovers to observe what the results of this wide fusion will be on the engines which will be put into service on the respective roads.

J. Russell Howden.

St. Peter's Vicarage,
Southborough, Kent,
April, 1923.

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LONDON AND NORTH-WESTERN RAILWAY

THE first edition of *Locomotives of the World* coincided with the appointment of Mr. C. J. Bowen Cooke as Chief Mechanical Engineer of the London and North-Western Railway. This second edition was in course of preparation when the sad news came of his death. Accordingly it seems appropriate that this edition should chronicle some of the locomotive developments which marked his tenure of the chieftainship at Crewe. Mr. Bowen Cooke was a son of the rectory, his father being Rector of Orton Longueville, Huntingdonshire, and two of his brothers are clergymen. He went to Crewe as an apprentice in 1875, when he was a lad of sixteen, and remained in the service of the London and North-Western all his life.

The "Precursors" and "Experiments" introduced during his predecessor's short tenure of office have been continued under Mr. Bowen Cooke. Many of both classes of engine have now been equipped with superheaters, and in addition somewhat modified locomotives of much the same general types have been brought out.

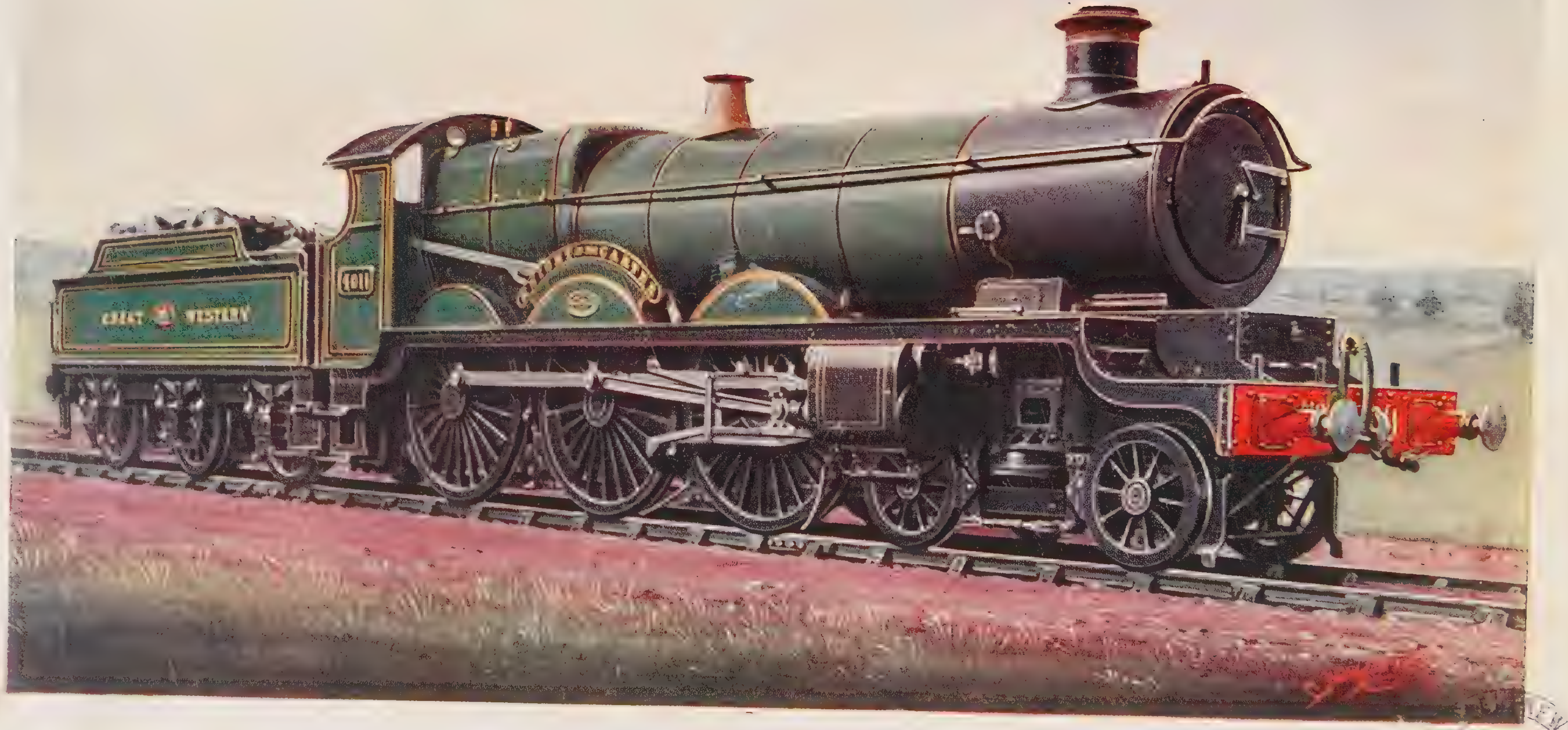
These are known as the "George the V" class and the "Prince of Wales" class respectively. The former were the first express engines built to Mr. Cooke's designs. They had larger cylinders than the "Precursors" and were fitted with piston valves and superheaters of the Schmidt pattern. The next engines to be built were some big 4-6-2 tanks, some of which have superheaters, while the others use ordinary saturated steam. They were the first locomotives on the London and North-Western to be built with Belpaire fireboxes.

In 1913 came the first of the famous "Claughtons." Like the "Experiment" and "Prince of Wales" classes, they are of the 4-6-0 type. But they differ considerably in details. They have Belpaire fireboxes and four cylinders, all of which drive on to the leading coupled axle. The cylinders measure 16″ in diameter by 26″ stroke. Steam is provided by a boiler having a total heating surface of 1745·4 sq. ft. This is made up of 1087·9 in the ordinary boiler tubes, 486·3 in large smoke tubes, as they are called, and 171·2 in the firebox. In addition, there is a superheater service of 413·6 sq. ft. The grate area is 30·5 sq. ft. and the working pressure 175 lb. to the square inch. In this engine the Joy valve-gear, which has been so long used on the North-Western, has been replaced by the popular Walschaert type for the outside cylinders. The coupled wheels are 6′ 9″ in diameter, and the bogie wheels 3′ 3″. The engine weighs 77 tons 15 cwt. in working order: 18 tons 15 cwt. is carried by the leading truck, the remaining 59 tons being available for adhesion weight. One of the latest engines of the class, No. 1914, has been named "Patriot." Under the name plate is the following inscription: "In memory of the fallen London and North-Western Employees 1914–1919." The number plate of this engine has a black background instead of the usual vermilion colour and is without the usual lining and panelling. This engine came out in August 1920, and is a worthy and suitable memorial of those brave men from the company's service who gave their lives in the Great War.

The "Claughtons" are strikingly handsome engines. The amateur might be inclined rashly to venture a criticism on the very moderate amount of boiler power provided. As a matter of fact it is only 150 sq. ft. more than was given the "Precursors" of sixteen years ago. But I must confess that for all this serious limitation they are good pullers. Of course, as we all know, the speed of all trains was very much slowed down after the war began, and during the war, with its serious shortage of locomotive power, engines on British Railways were set to do things which would never have been demanded of them in the ordinary course of working. I remember very well one afternoon standing on Crewe platform and watching a "Claughton" starting off southbound with no less than 450 tons behind the tender.

Of their capacity for hard work there can be no question; only, as I say, it seems strange to the outsider that, having produced such a fine engine, Crewe should have kept it relatively so small.

As superheating for locomotive purposes has been coming very much into evidence all the world over during the last decade, I may just try to add here a few words in explanation of the system. There are few roads in Europe which are not now experimenting with the superheater with more or less extended service, and many engineers in England and America are studying the same question. The devices are various, and I will not stay to describe them in detail, but the



Ready for the Lists: A Great Western "Knight."

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principle is one, and of that we may try to get some idea. First of all we must remember that the amount of work done in any steam-engine depends upon the range of temperature through which the steam passes while doing its work. In other words, the more heat our engineer can extract from a given quantity of steam while it is expanding in his cylinders, the greater will be the efficiency of his engine. Now, in order to get a great deal of heat out of the steam, you must first put a great deal in. You will never get out all you put in, but the more you do put in to start with the more you will have to draw from while the steam is in your cylinders.

The next thing to remember is that in ordinary steam, saturated steam as it is called, the temperature depends upon the pressure. How close this dependence is the following little scale will show:

PRESSURE IN LBS. PER SQ. IN.	BOILING POINT IN DEGREES FAHRENHEIT
Normal	212
25	240
100	327·6
150	358·3
200	381·7
250	401

Now we can see the reason for the increase of steam pressure in the locomotive boilers of the last few years. So soon as ever the boiler-makers, by improved methods of working, were enabled to build their boilers sufficiently strong to withstand it, the engineer was ready and anxious to take advantage of their advance to increase the pressure of steam for his engine's use.

But, of course, to build a boiler that will carry 250 lbs. costs a good deal more than to build one that has only to carry 150. And here comes in the inducement to try superheating the steam. This is done by heating the steam while allowing it to expand. As this takes place the steam becomes freed from the watery particles of which saturated steam, as its name implies, is full, and approaches to the condition of a perfect gas. It might now be supposed that our locomotive engineer might heat up his steam to any reasonable degree he wished, and so materially reduce his boiler pressure and cost of building. Here, however, a difficulty comes in, which, though at first sight it seems trivial, is really a formidable obstacle. Experience shows that the watery particles of saturated steam act to some extent as a natural lubricant in the cylinder. Now the dry heat of steam which has passed through a superheater is devoid of this lubricant; consequently there is a serious tendency to heating and cutting the linings of the cylinders. The net result seems, then, to be that a moderate amount of superheating may be usefully adopted, and this is what, as the present volume shows, is being widely done to-day.

RAILWAY OPERATING DIVISION

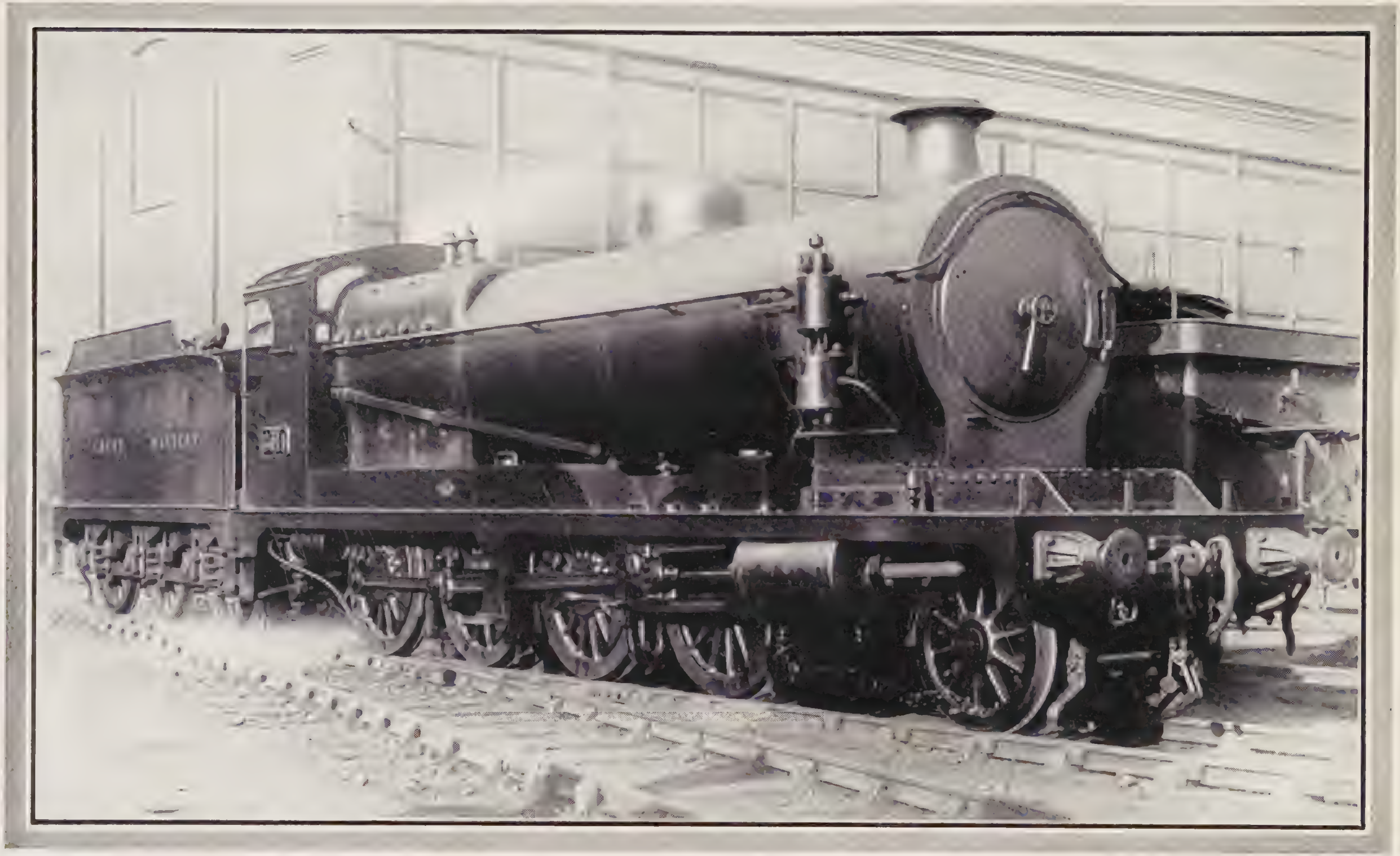
THE war was unprecedented in many ways, among others in its tremendous demand for transport. In the response to this demand railroading took its full share. The Western front lay in a territory already supplied with a network of railway lines, while during the long-drawn-out course of the conflict many new lines were rapidly built to facilitate the movement of men and material. Many of these new lines were just light railways hastily built to serve a particular part of the front. These varied from little trench railways up to standard-gauge lines in direct physical connection with the existing French and Belgian railways. At a very early stage in the operations the whole of these railways, so far as they served the British front, were handed over to the British military authorities, and a special department called the Railway Operating Division was created to work them. The lines under its charge were partly certain sections of the French and Belgian railways, and partly emergency lines built by the Army itself. Moreover there were widely exercised running powers over other lines. Thus, for instance, the Railway Operating Division sometimes worked trains to and from Calais and other points on the Nord system ; so that, besides the track actually handed over to the military authorities, there was a considerable amount of train and engine mileage to be run over what would be called in British railway parlance "foreign" lines.

It was a fortunate circumstance that the French standard gauge is so nearly identical with the British. While the latter is 4′ 8½″ the former is 4′ 8$\frac{11}{16}$″. It thus happens that, while ordinary French rolling stock could not run on English lines without special adaptation, yet English rolling stock could work on the French lines. French trains would be almost certain to become "gauge-bound" on any English curve. But English trains are merely rather a loose fit on French track. This simplified the matter of providing rolling stock for the Railway Operating Division. The French and Belgian railways had lost large amounts of their own stock to the invaders, and the former in particular were hard put to it to find enough railway material for the supply of their long battle front. It was therefore hopeless for the British Railway Operating Division to try to find help in this direction, and so, almost from the outset of the war, British engines were despatched to France. Then, too, the wear and tear on the locomotives was very severe, to say nothing of losses due to enemy action. In course of time, big repair shops were established in various places, the biggest being at St. Étienne, near Rouen.

The first English engines to go across to France belonged to the South-Eastern and Chatham Railway. These were five old 0-6-0 side tanks built for the London Chatham and Dover Railway from the designs of Mr. Kirtley. They were used for shunting at Boulogne from the early days of the war. Perhaps the next engines to be acquired were some large 4-6-4 tanks which had just been completed for the Dutch State Railways by Beyer, Peacock & Co. There were 15 of these taken over. As we remember only too well, the advancing German hordes overran nearly all Belgium. Very little of the Belgian railways was left which had not passed into the invaders' hands. But as the Belgian armies retreated they were able to send a good deal of their railway rolling stock on before them to safety. With the limited extent of front assigned to their army to hold, much of this material was not required by them, and was accordingly handed over to our Railway Operating Division. About 250 Belgian locomotives were at one time in British service and in charge of the British staff. These comprised examples of more than 40 different types. They ranged from old curiosities dating from the 'sixties down to the most modern British and American built engines.

Further, some hundreds of locomotives were loaned by the various British railways. The London and North Western alone sent 111 engines. The English engines borrowed were mostly goods engines, either 0-6-0 or 0-8-0; the others were tank-engines. It must be remembered that not all of these went to France. A considerable number were despatched to Salonica and to Egypt.

Then, lastly, the heavy requirements of the armies were met by building. For this the Railway Operating Division naturally went first to British builders. But then, as these became overwhelmed with other urgent orders for munitions in the narrower sense of the word, railway orders had to be placed farther afield. Of these outside orders the Baldwin Locomotive Works in America secured the lion's share, and many consolidations and ten-wheelers especially were shipped across the



Peace after War: Railway Operating Division "Consolidation" Type Engine in service on the Great Western Railway

Atlantic to work in France. These represented practically the Baldwin Company's standard types, and could therefore be obtained quickly.

It so happened that in England also the consolidation type had been making its way for some time as an acceptable class of engine for heavy goods traffic. Various British lines had put a considerable number of these engines into service. The military engineers selected the particular design worked out by Mr. Robinson for the Great Central Railway, and 295 locomotives were built to this plan by various British makers. I am able to illustrate, through the kindness of the builders, one from the shops of the North British Locomotive Co. at Glasgow.

To facilitate comparison I have arranged the chief dimensions of these and the American-built class in tabular form.

	CYLINDERS	DRIVING WHEELS	LEADING WHEELS	HEATING SURFACE		SQ. FT. TOTAL	SUPER-HEATER	GRATE AREA. SQ. FT.	PRESSURE WORKING	WEIGHT OF ENGINE IN WORKING ORDER
				Firebox	Tubes					
North British Co.	21×26	4' 8"	3' 6"	153	1348	1501	255	26·25	180 lb.	73·85
Baldwin Co. .	21×28	4' 8"	2' 9"	181	2332	2513	366	32·7	190 lb.	72·20

Since the Armistice, the borrowed engines have been gradually returned to their owners, and now the specially built engines are being distributed among different British lines. The one in our picture has got into hands of the Great Western Railway, and has a standard Great Western tender attached. It will be interesting to see whether this intermingling, and to some extent standardizing, of locomotive design turns out to be one of the by-products of the war, and, if so, what its effect on the general progress of locomotive building in Great Britain will be.

GREAT WESTERN RAILWAY

No railway in Great Britain presents at the present time, or has done for some little while past, quite so many features of interest in its locomotive department as does the Great Western. Not even in the stirring days of the broad gauge and the tremendous single express locomotives of Brunel and Gooch was the locomotive department the scene of bolder experiments or the road itself the scene of finer locomotive work than it is at the present time. Readers of the 1909 edition of *Herbert Strang's Annual* will remember that there I dealt in some detail with the largest and most interesting engine on the whole line, the famous "Pacific" type, "The Great Bear." This engine was avowedly built as an experiment, and although, as we shall see in the course of the present volume, a great many of the leading railroads, both in Europe and America, are now putting engines of this type into service, yet in Great Britain the Great Western stood alone in possessing an engine of the type. That solitary example has now been converted into an eight-wheels-coupled consolidation-type coal engine. By the time this is in print both the Great Northern and the North Eastern will have "Pacifics" at work. In the present chapter I want to take a step backward and consider a little further one of the two types of locomotive which have coalesced into the Pacific.

Our illustration presents us with a view of one of the large ten-wheeled engines of the "Knight" class which Mr. Churchward has put into service. These "Knights," we may observe, came out at about the same time that "The Great Bear" appeared. The previous set of ten-wheeled engines had been called after the names of stars and are known as the "Star" class. They therefore appropriately found culmination in the huge Pacific bearing the name of a constellation. Like the Pacific, all these 4-6-0 engines both of the "Knight" and "Star" classes are four-cylinder simples. The first Great Western ten-wheeled engine came out in the year 1902 and had a pair of large 18″ by 30″ cylinders. This engine was numbered 100, but did not, at first, receive any name. It had a large boiler with a maximum diameter of 5 feet and a barrel 14′ 8″ long. This boiler afforded a total heating surface, including firebox, of 2410·31 sq. ft.

Another engine of the same general dimensions came out in the following year bearing the running number 98. Although almost identical in design and measurements with her predecessor this engine only had a heating surface amounting to 2142·91 sq. ft. This reduction in nominal heating surface was caused principally by the fact that the number of tubes in the boiler was reduced from 287 to 250. As I have explained in some detail in an earlier volume, to which reference will occasionally be made during the course of these notes, a reduction in the number of boiler tubes may actually improve the steaming qualities of an engine, in spite of the nominal loss of power, owing to the improved circulation which may result from a better arrangement of the tubes which remain.

About this time Mr. Churchward arranged for a French-built De Glehn compound to be brought over with a view to extended trials on the Great Western. This engine was built by the Société Alsacienne at Belfort and was an "Atlantic" very similar in general dimensions to the engines then doing such good work on the Northern Railway of France. I have inserted a comparative table of dimensions of some of the De Glehn "Atlantics" in the article on the new Bengal-Nagpur engine, and as the leading particulars of the De Glehn for both the Nord and the Great Western appear there I need not repeat them. To compete with the French compound one of the Swindon ten-wheelers, No. 171, was equipped with a boiler to carry a working pressure of 225 lb. instead of the usual 200, the working pressure in the compound being about 227. No. 171 was, after a few months' working, altered into an "Atlantic," the rear pair of drivers being removed and replaced by a small pair of trailing wheels. This alteration initiated an extensive series of experiments in actual train working between "Atlantics" and six-coupled engines on the one hand, and between simple and compound locomotives of the former class on the other. He would be a rash man who should affirm that any conclusive results would ever be established in locomotive engineering, but the present state of affairs on the Great Western seems to be somewhat as follows.

Mr. Churchward is not apparently satisfied that the trouble and expense of compounding really pays, for all the engines of his own build are simples. But, on the other hand, the experiments with the French engines seem to have convinced him that one feature of their design at least has a permanent element of value. The feature to which I refer is the use of four cylinders instead of two to take the large supply of steam which is afforded by over 2000 sq. ft. of heating surface. Accordingly all the recent big express engines have been four-cylinder simples. This arrangement gives the advantages inherent in a subdivision of the driving force of the engine without the added complications consequent upon the introduction of compounding. All moving parts, such as connecting and eccentric rods, being duplicated, each one becomes much lighter than the corresponding part in a two-cylinder engine of similar size and power. More important still, there is the opportunity afforded of obtaining an almost perfectly balanced engine while at the same time doing away with most of the objectionable balance weight which is ordinarily built into the circumference of the driving wheel.

As compared with four-cylinder compound type there is no need, in these simple engines, to provide for a varying rate of cut-off in high- and low-pressure cylinders. This need, in a compound, arises naturally from the great difference between the pressure of the steam as it enters the high-pressure cylinders and as it enters the low-pressure. Thus it comes about that a high-pressure cylinder, to work economically at high speed, needs to have steam cut off after the piston has travelled perhaps only one-fifth of its stroke, while the low-pressure cylinder cannot be robbed of its supply of steam until more than half the distance of the stroke has been travelled by the piston. To provide for this necessary variation renders some kind of variable valve gear imperative in a compound. This complication the simple escapes. On the other hand it also loses the advantages of compounding, such as the more complete utilization of the latent energy of the steam and the softer exhaust. But in a locomotive you cannot have it every way, and it is this constant necessity for trimming and balancing and compromising between ideals which, under the circumstances, are mutually exclusive which gives to locomotive engineering so much of its fascination.

As to driving-wheel arrangement, the "Atlantic" type seems to have been definitely abandoned at Swindon in favour of the six-coupled ten-wheeler, with, of course, "The Great Bear," No. 111, as at least an experimental combination of the two rival forms of the modern express engine. Most, if not all, of the Swindon-built "Atlantics" have been now converted to the 4-6-0 type, and I believe that, at the moment of writing, the three French engines are the only 4-4-2 engines now running on the Great Western Railway.

The "Knight of the Garter," like most of the other ten-wheeled express engines, has a boiler giving 2142·91 sq. ft. of heating surface and carrying a working pressure of 225 lb. per sq. inch. Each of the four cylinders measures 14¼ inches in diameter with a 26-inch stroke, and the steam supply is controlled by means of piston valves. Cylinder and valve chest are enclosed in a neat casing, as will be seen from our illustration. The driving wheels measure 6′ 8½″ in diameter, and all wheels, including the bogie wheels, are braked. The engine weighs about 76·7 tons in working order, and the tender, which is fitted with a water scoop, another 40 tons.

The locomotive-building activities of the Great Western Railway have since 1914 mainly been directed to the provision of new and powerful types of goods and mixed traffic engines. These years have only seen two fresh types of passenger locomotives turned out. These are the "Kings," the first of which, "King Edward," No. 4021, came out in 1910, and the "Courts." The first of this class was the "Arlington Court," No. 2931. The ten engines in this set were all completed towards the end of 1911. The "Kings" are four-cylinder engines fitted with superheater. The "Courts" are also superheater engines, but in cylinder arrangements they revert to the plan of the "Saint" class and have two cylinders 18½ × 30. All these engines are ten-wheelers and in that respect are like the one illustrated here. For the time being therefore it seems as if Swindon had reached something like finality in the general design of its express engines. A newer and bigger boiler has now been introduced. This will affect all classes of main-line engines. The new boilers have already been fitted to mixed-traffic locomotives of the consolidation and mogul types.

SOUTH AFRICAN RAILWAYS

When the Union of South Africa was consummated on May 31, 1910, the railways which had up to that time been the property of the various States became amalgamated under the above title. These systems were the Cape Government Railway, the Natal Government Railway and the South African Railways belonging to the Transvaal and Orange River Colony. The total mileage involved amounted to 7042. Since that date about 2500 miles of new track have been built. Including some privately owned lines and lines in the Protectorate of South-West Africa, the railways in South Africa at the end of 1918 reached a length of 11,443 miles. In addition to these, other routes are now open to points outside the Union, such as Lourenço Marques on the east and Bukama in the Congo on the west. The last mentioned is interesting as providing what is at present the longest all-rail journey from Cape Town, the distance via the Victoria Falls and Broken Hill being just 2600 miles. Moreover, some day it is hoped that through railway connection may be established between Cape Town and Cairo. This consummation is yet a long way off, as may be seen from the table of distances which is given on next page.

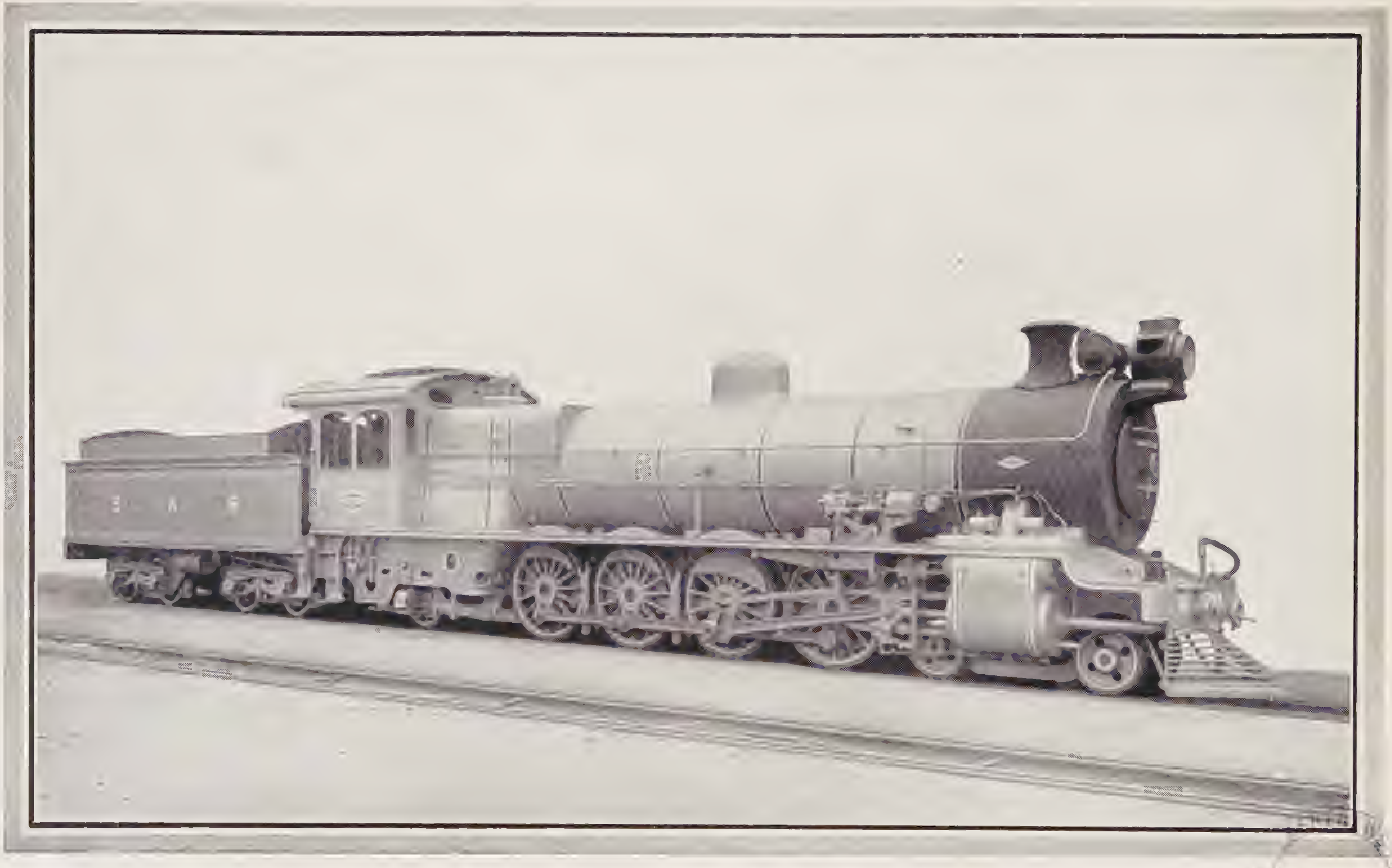
When this great through route has been completed as a railroad all the way it will be more than twice as long as the Canadian Pacific line between Quebec and Vancouver. It will then rank as one of the very greatest railroads of the world. As it is, we may compare the 2600 miles to Bukama with the 3078 miles of the great Canadian road. But if ever the railroad track is opened throughout, there will arise one of the biggest break of gauge difficulties in the world. For the Egyptian and Sudanese lines in the north are 4′ 8½″, the world's standard gauge, while the South African and Congo lines coming up from the south are all laid to a gauge of 3′ 6″, the South African standard.

So much for the general railway situation seen from the standpoint of the S.A.R. Now let us look a little at the more specific problems the Administration has to meet. The bulk of their traffic originates in connection with the Rand and the Natal coalfields. Johannesburg is easily the biggest market for produce in all South Africa, and accordingly there sets in that direction a continual stream of traffic of all sorts: cattle and farm produce from Rhodesia in the north and the Free State in the south; coal from Natal; machinery, hardware and soft goods from the seaports of Cape Town or Durban.

STAGE		DISTANCE MILES	MODE OF TRAVEL	TIME IN DAYS
Cape Town	to Bukama	2600	Rail	8
Bukama	Kabalo	402	Steamer	6
Kabalo	Albertville	166	Rail	1
Albertville	Kigoma	50	Steamer	1
Kigoma	Tabora	260	Rail	1
Tabora	Mwanza	200	Road	8
Mwanza	Jinja	190	Steamer	2
Jinja	Namasagali	61	Rail	1
Namasagali	Masindi Port	101	Steamer	1
Masindi Port	Butiaba	63	Motor	1
Butiaba	Nimule	165	Steamer	2
Nimule	Rejaf	105	Track	6
Rejaf	Kosti	890	Steamer	10
Kosti	Wadi Halfa	816	Rail	2
Wadi Halfa	Shellal	208	Steamer	2
Shellal	Cairo	555	Rail	1
		6832		53

So much for the economic; consider now the geographical aspects of the situation. The interior of South Africa consists of a high plateau. This plateau in the Orange Free State takes the form of a vast grassy plain. Further west it is more broken by kopjes. The height of this plateau may be gauged from the altitude of Bloemfontein and Johannesburg, to take two chief examples. The former is 4568 and the latter 5735 feet above sea level.

The table-land connects with the flat coastlands through a broken stretch of mountainous country of great beauty. You come from Cape Town by the Hex River Pass to De Aar; or from Port Elizabeth along the Fish River to Norval's Pont; or from East London through Amabele and Blaney to join the Port Elizabeth line; or from Durban via Pietermaritzburg and Ladysmith and through the Laing's Nek



Across the Great Karroo: Powerful "Mountain" Type Engine for the South African Railways

Tunnel into the Transvaal. In either case, the engineering features of the road are much the same and full of interest.

The 3′ 6″ gauge track is very closely adjusted to the contour of the country. The train twists and turns among the rocks, and sometimes for miles on end you never seem to see a straight quarter of a mile. Standing on a car platform about the middle of the train, you see at one time the whole of it from locomotive to caboose, only the two halves of it are moving in opposite directions. Then there comes a fresh turn in the line, and your platform for a minute seems to project into space. You see nothing but the two adjacent cars bending away from one another at an acute angle.

At one point in the Hex River Pass there is a speed limit of 22 miles an hour enforced against south-bound trains for ten miles at a stretch. All trains in South Africa, goods as well as passenger, are equipped with the automatic vacuum break, otherwise they could never be held on those long grades. Even so, wrecks sometimes happen.

Once coming down the Hex on my way to Cape Town I saw the remains of a coal train which had run amok only the week before. It was just on a nasty **S** curve. The whole train had left the track and was scattered over the slopes of a ravine. They handle the heavy Transvaal coal traffic in big 40–50 ton bogie cars. It was a sad sight to gaze at all this fine rolling-stock lying battered and broken on the scrub-covered and rocky ground while our train slowly and cautiously crept past.

For helping freight trains up these heavy grades the South African railways employ a certain number of 0–6–6–0 Mallet compounds. The arrangement is similar to that of the engine for the Burma railways illustrated in the present volume. The South African engines are, however, much bigger. Failing one of these engines, which were specially built for such work, any of the 8-coupled classes are used.

This brief sketch of the railway conditions in South Africa will, I hope, enable us to appreciate something of the difficulties and problems which its railway engineers have to solve. Part of their solution is found in the provision of suitable locomotive power; and the engine in our picture belongs to one of the latest types built to the designs of Mr. Hendrie, the locomotive superintendent. Most of the later classes of engines for South Africa generally, and for the S.A.R. in particular, have been provided with eight coupled wheels, and it will be seen that No. 1799 conforms to this type. In order to ease this long coupled wheel-base round the sharp curves of which I have spoken, the leading pair has flangeless tyres, termed blind tyres. Also, as will be seen from the illustration, there is a jointed coupling rod between the third and fourth pairs of wheels. By means of these the rigid wheel base is reduced to only 10 ft. There is a similar but slightly more powerful class in which the wheel base has been kept down to 9 ft., but in this case the diameter of the wheels in 6 inches less.

In the engine illustrated the diameter of the coupled wheels is 4′ 9″; the leading bogie has wheels 2′ 4½″; and the trailing pony truck under the fire box has 2′ 9″ wheels.

The cylinders are simple expansion measuring 22″ × 28″. Steam is admitted through piston valves which are controlled by gear of the Walschaert type. Power reversing gear is provided as well as forced lubrication, which is demanded by the superheating of the steam. The boilers of these various types which have come from the shops of the same builders are all of the straight-top pattern. The one shown has a total heating surface of 2026 sq. ft. This is made up of a tube heating surface amounting to 1834 sq. ft., while the firebox provides the remaining 192 sq. ft. In addition there are 549 sq. ft. of superheater surface. In the yet more powerful engines of 1500 class the tubes give 2312 sq. ft.; the firebox 158; total 2470; and the superheater gives 669 sq. ft. In both classes the firebox has a grate area of 40 sq. ft., and in both the firebox is of the Belpaire pattern, shown by the square shoulder-piece projecting beyond the barrel of the boiler.

The cab is large and commodious and provided with seats for the enginemen. The electric head-light will be noticed. This is provided with a double lamp. One is a small glow lamp and the other a searchlight. The former is used when the engine is at a station or standing on a siding, or when running over a civilized portion of the route. Such portions exist round the big centres like Cape Town, Johannesburg, or Bloemfontein. There you have double, or perhaps quadruple tracks, block signals, and a frequent service of trains of various sorts. Here a dazzling searchlight should be a nuisance and a danger. But out among the mountains or on the lonely veldt it is another matter. There the searchlight comes into play whenever the engineer may find it necessary. It is a fine sight to watch the Johannesburg express, perhaps double-headed with two of these big engines, threading its way by night among the precipices of the Hex.

The tender has capacity for 450 cubic feet of fuel and 4250 gallons of water; but often this large supply is not sufficient. In such situations a large bogie tank car is hitched behind the tender. This is a detail of daily working over certain sections where the water supply is either small or not of sufficiently good quality for locomotive needs.

These fine engines were built by the North British Locomotive Co., to whom I am indebted for the specifications and photograph.

CALEDONIAN RAILWAY

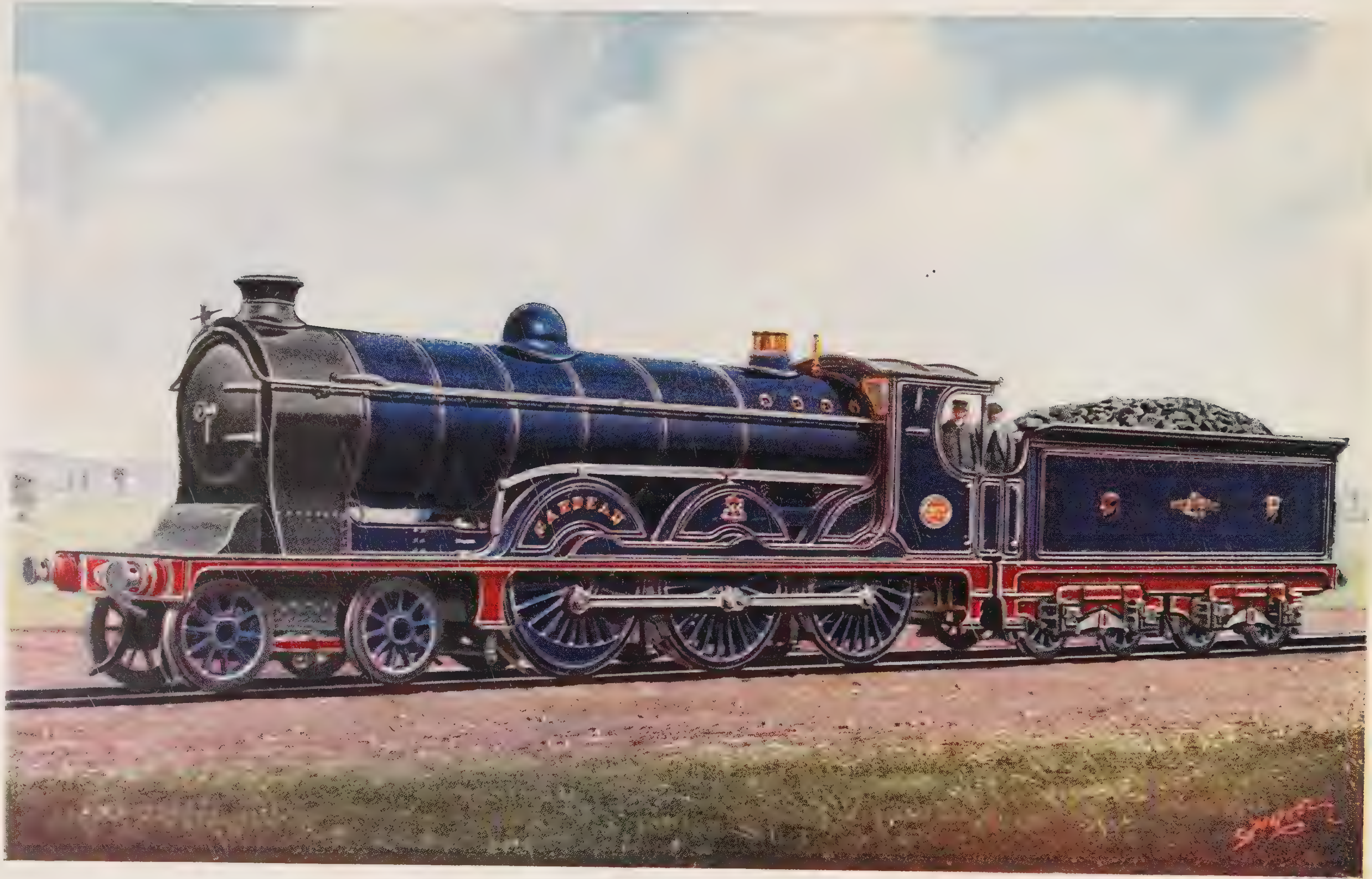
Mr. J. F. McIntosh is a striking example of a man who has worked his way up from the ranks. In 1860, when only fourteen years of age, he entered the Arbroath shops of the Scottish North-Eastern Railway, long since absorbed into the important system at the head of whose locomotive department he stood so long. After thirty-five years' service in various grades and positions he was appointed Locomotive, Carriage and Wagon Superintendent in the early part of 1895. Since then, the Caledonian Railway has stood in the very front rank of British locomotive practice, and the remarkable series of designs, of which a tabular recapitulation accompanies the present article, is sufficient to mark their designer as one of the leading locomotive engineers of the day.

Two broad features have marked all Mr. McIntosh's work. In the first place he was one of the earliest in Great Britain, if not the earliest, to recognize that the old proportion of boiler power to cylinder capacity were altogether wrong. Engineers had been giving their engines cylinders in many cases much too big for the amount of steam which the boiler was capable of generating. The new Caledonian chief saw that boiler power, and not cylinder capacity, was the real measure of an engine's usefulness, and he at once began to increase the size and power of the boilers with which the locomotives under his care were to be equipped. The other marked feature of all Mr. McIntosh's engines has been their simplicity of outline and design. There has been no experimenting with compounding or new and strange valve gears, but always each new engine has followed the plain simple lines of its predecessors, just a sturdy, straightforward sort of giant, a fit epitome and representative of the national character of the country of its birth.

For the first six years of his locomotive superintendentship the new chief contented himself with eight-wheeled after-coupled engines of gradually increasing boiler power. The most renowned of the three classes of engines which followed this general type were the famous "Dunalastairs" which came out in 1898. No. 766 of this class bore the name, the others, like the majority of the Caledonian engines, having only numbers. These locomotives with their 1500 sq. ft. of heating surface and 19-inch cylinders did remarkably good work, being especially renowned as hill climbers. In 1902 a further step forward was taken in the design of a class of ten-wheeled engines for working over the very hilly grades of the Oban and Ballachulish lines. These locomotives, like their predecessors, had 19-inch cylinders, but the heating surface was increased to 1905 sq. ft., while the driving wheels were only 5′ 0″ in diameter. Four years later another class of 4-6-0 engines with 5′ 0″ drivers was brought out. These fine locomotives are intended for working heavy fast goods traffic, but are of course also available for passenger service when required.

Nineteen hundred and three saw the first of the large ten-wheeled express engines for this railway. This was not the first engine of the kind in Great Britain, for the type had been introduced on the North-Eastern by Mr. Worsdell in 1899, but it marked the combination of a very powerful boiler with six coupled driving wheels. The engine illustrated in our picture is one of a class which began to appear in 1906, and is a modification of the 49 class. The chief difference between the two sets of locomotives is that the later ones have cylinders one inch smaller than the earlier, and also a very slight reduction in heating surface. The fixed wheel base has also been modified, being increased from 6′ 8″ to 7′ 0″ in the newer engines. It should be added that there were only two engines of the original class built, bearing numbers 49 and 50, and the "Cardeans" may be looked upon as the standard ten-wheeled express engines of the line.

A curious feature of Mr. McIntosh's 4-6-0 engines, whether express, passenger, or goods, is that they all have inside cylinders, and in all the leading coupled wheels are the drivers. It will be remembered, perhaps, that in this last particular, some engines of similar design for the Caledonian's great ally, the London and North-Western, have followed the example set them by the northern company. But I think I am right in saying that the plan, so far as big engines are concerned, is confined to the practice of these two roads. It seems presumptuous to criticize engines which have been so markedly successful as these fine examples of locomotive design, but one cannot help feeling that there is more symmetry in a six-coupled engine in which the centre pair of wheels is the drivers, than in one where the power is applied at one end, so to speak. Another point that follows on this arrangement is that a comparatively short connecting rod is the result. This again



A Sturdy Hill Climber: Ten-wheeled Express Engine, Caledonian Railway.

seems to be open to criticism, because the shorter the rod the smaller the angle which it makes with the piston rod when at the centre of the stroke, and consequently the less direct the transmission of power at that point. The special idea governing this feature of the design has been no doubt the retention of the inside position for the cylinders. But this again is coming to be a matter of questionable advantage with cylinders so large as those of the "Cardean" and her sisters.

From the foregoing remarks it will be inferred that these fine engines are not so much theoretically perfect as practically efficient. This point comes out in other ways. Thus, for instance, we have seen in various instances in the present series of notes how much attention is now being paid by locomotive engineers to the matter of balancing their engines by means of the use of four cylinders instead of two. But, big as are the biggest Caledonian locomotives, they are all balanced in the old-fashioned way, as is hinted in our picture. So, too, other modern devices, such as compounding and superheating, are all foreign to the simplicity and directness of the great machines turned out from St. Rollox under Mr. McIntosh's régime. At any rate, whatever we may say about points like these, it will be readily admitted by all that these engines are both handsome to look at and efficient in work.

Mr. McIntosh retired from the service of the railway in 1914, and less than four years later he died. He has been succeeded by Mr. W. Pickersgill. And it is of interest to observe that the new locomotive chief has sought to improve his predecessor's design in the very point about which criticism was offered in the preceding paragraphs. For in 1917 a new series of 4-6-0 engines began to appear. These have outside cylinders driving on to the centre pair of coupled wheels. The driving wheels of these engines are only 6′ 1″ in diameter. The cylinders are an inch larger in diameter than the McIntosh engines. Superheating has been introduced, and the total heating service proportionately reduced. Other details will be found in the table on page 30.

A few other details of No. 903 than those given in the table will be of interest. The boiler barrel, which is of the straight type, is 17′ 7⅞″ long, with a mean diameter of 5′ 3½″, 3⅜″ longer and 3½″ greater in diameter than the boiler of No. 49. There are 270 tubes, of which 257 are 1¾″ in diameter and the remainder 2½″, all being 16′ 8″ long between tube plates. The grate area, both of No. 49 and No. 903, is 26 sq. ft., while the latter engine has a heating surface in the firebox amounting to 148·25 sq. ft., as against 145 sq. ft. in the earlier. Both weigh 73 tons in working order and both have tenders running on two four-wheeled bogies. But the tender of No. 49 weighs 55 tons, while that of the engine illustrated weighs 2 tons more. Both tenders carry 5000 gallons of water, and the tender in our picture has 6 tons of coal on board, while the earlier tender carries 5 tons. This comparatively large amount of water carried is rendered necessary by the absence of any pick-up apparatus by which the supply might be renewed while running.

Comparative Dimensions of Certain Classes of Locomotives for the Caledonian Railway

NUMBER	NAME	DATE	TYPE	DIAMETER OF DRIVING WHEELS	CYLINDERS DIAMETER × STROKE	BOILER HEATING SURFACE	WORKING PRESSURE
					inches	sq. ft.	lbs.
721		1896	4–4–0	6′ 6″	18¼×26	1403·2	160
766	Dunalastair	1898	4–4–0	6′ 6″	19×26	1500	175
900		1899	4–4–0	6′ 6″	19×26	1600	180
600		1901	0–8–0	4′ 6″	21×26	2500	180
55		1902	4–6–0	5′ 0″	19×26	1905	175
49		1903	4–6–0	6′ 6″	21×26	2400	200
140		1904	4–4–0	6′ 6″	19×26	1615	180
903	Cardean	1906	4–6–0	6′ 6″	20×26	2360	200
908	Sir James King	1906	4–6–0	5′ 9″	19×26	2178	180
918		1906	4–6–0	5′ 0″	19×26	2018	175
62		1917	4–6–0	6′ 1″	20×26	1934·25	170

The main line of the Caledonian Railway is fairly straight but rather hilly. It runs from Carlisle, where it joins the London and North-Western, to Carstairs, Coatbridge, Dunblane, Perth, Forfar and Aberdeen, a total distance of 240½ miles. The worst place on the main line is the well-known Beattock bank, 9¾ miles long, at an average gradient of 1 in 75. The through expresses are now mostly helped up this bank in spite of the big engines such as we have been studying together.

Nominally the longest run at present to the credit of the Caledonian is from Carlisle to Stirling, 117¾ miles in just two hours and a half. This gives an average speed of almost exactly 47 miles an hour. Such a figure represents a sad falling-off from the timing of pre-war days. It is only part of the deceleration which has been forced upon British Railways by reason of the coal shortage under which the whole country has been suffering. It should also be remarked that this particular train has usually a locomotive stop at Beattock, 39¼ miles out of Carlisle.

The fastest booked run on the Caledonian and the fastest one in all Great Britain used to be that between Forfar and Perth. This is a distance of 32 miles, and one train daily south-bound was timed to do the run in 32 minutes.

FRENCH STATE RAILWAYS

FRANCE in some of its aspects resembles India: it is very largely an agricultural country, and it has comparatively few large towns. But, on the other hand, its railways form essential links in many international through routes; and in this its circumstances are of course quite unlike those of India. To the north-east and south-east its railways form integral parts of trans-European lines of communication. To the south also the Paris–Orléans has some importance in this way, since it affords connection with the Peninsula; and in the north-western corner of France the State Railways handle the English traffic via Dieppe and also via Havre, and American traffic off the Atlantic steamers at Cherbourg.

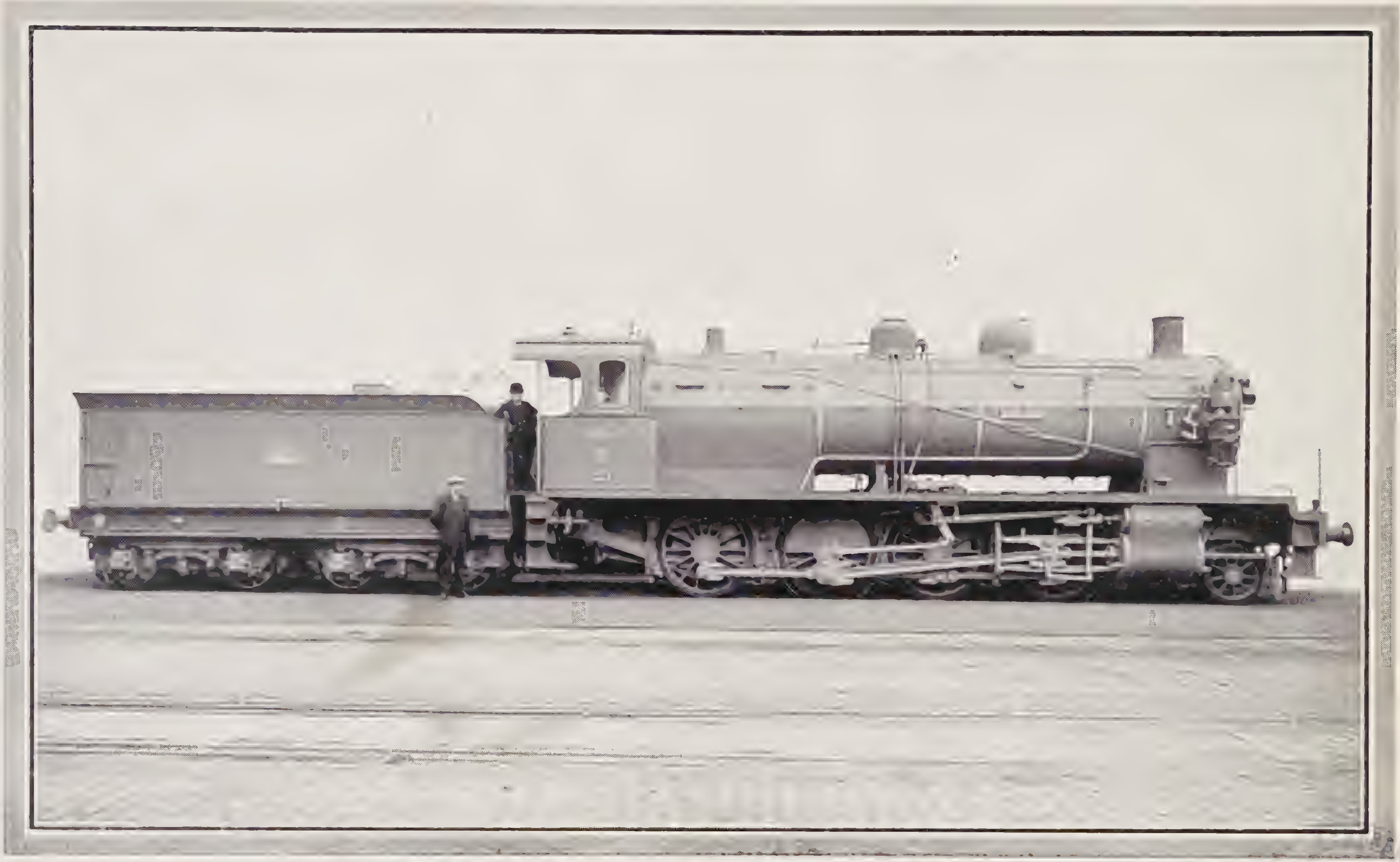
But the Midi in the south, and still more the old State lines, are chiefly of local importance. The original main line of the State system runs from Paris to Bordeaux via Chartres, Saumur, Thouars and Niort. The distance is 381 miles, and the road is unique among French railways in that it is the only line on which water troughs have been laid down after the English fashion. This enables the run between Chartres and Thouars, 147¾ miles, to be made without a stop, which is, I suppose, easily the longest run in France.

Besides the main line, the State Railway has a tangle of branches stretching out on either side. These nearly all join up with the Western Railway on the north and with the Paris–Orléans Railway on the south. And it will be remembered that in 1913 the Ouest was taken over by the State, so that the system has now a compact monopoly covering all the north-western *departements*.

In common with other French lines, the State was severely crippled in its rolling-stock by the war, and both English and American builders received large orders, especially for the replacement of locomotives. The engine illustrated is one of a number which have been built by the North British Locomotive Co. Many locomotives of the same general type have also been turned out by the American Locomotive Co., but these all possess more or less distinctively American features, and can be readily picked out from among their British compeers. The experience gained in the actual working of these differing though similar engines ought to afford valuable data as to the relative value of those methods wherein the practice of the two countries has diverged. These consolidation engines are built as simples, with cylinders measuring 23¼″ in diameter by 25$\frac{9}{16}$″ stroke. The awkwardness of these measurements is due to the fact that the specifications were drawn up in French, and the vulgar fractions represent the nearest British equivalents to the French dimensions. As expressed in millimetres, these are 590 × 650. The pony truck wheels are 2′ 9½″ in diameter and the drivers 4′ 8$\frac{11}{16}$″.

The boiler is of the straight-top type, and has a total heating surface of 1829 sq. ft. This is made up of 1647 sq. ft. in the tubes and 182 sq. ft. in the firebox. The grate area is 34 sq. ft.; the superheater surface 393 sq. ft., and the working pressure 170 lb. per sq. inch.

The valve gear is of the Walschaert pattern, which is standard to-day in France. Piston valves are fitted. The sand-box, as is very common in French practice now, is mounted on the top of the boiler. The peculiar method of numbering will be noticed. The first group of figures indicates the type, and the second the number of the engine among others of that class. 140 is the French way of indicating what in England and America is implied by the Whyte formula, 2-8-0. The explanation is that the French reckon by axles, while English and American engineers count the number of wheels. It is a mere matter of practice. But the inclusion of an indication of the class of an engine in its running number is peculiar to French railways, and even among them is not universal.



Among French Vineyards: Compound "Consolidation" Locomotive for the State Railways

ATCHISON TOPEKA AND SANTA FÉ RAILWAY

This is one of the biggest railways in the country of big railways. Its title is a sort of epitome of its history. Atchison is on the banks of the Missouri. Sixty years ago the traveller who crossed the river left civilization behind him and plunged into the wilds. West of the Missouri there were redskins and wild men, prospectors and adventurers, hunters and trappers, but no railway. Topeka is fifty miles south-west of Atchison; and perhaps it is not too fanciful to think of the first two names in the descriptive title of this railway as expressing the first hesitating steps which it took to the west. Santa Fé again is 802 miles west of Topeka, and suggests forcibly the next long stride taken by the early railroad pioneers towards the Pacific. Curiously enough, the town is not on the main line of the railway at all. It stands eighteen miles away at the head of a branch which connects with the great trans-continental road at Lamy.

Thus the Atchison Topeka and Santa Fé has long outgrown its name, for its main line to-day stretches from Chicago in the north-east right across the mountains to Ferry Point, San Francisco, a distance of 2569 miles. From Chicago to Newton, 659 miles, the road is double track. At Newton the line bifurcates into two single-track roads. The principal one keeps to the North and goes along the Arkansas Valley to La Junta, and thence via Albuquerque to Rio Puerco in New Mexico. The other line comes due south to Winfield in Kansas, and then south-west through Amarillo to the junction at Rio Puerco. From Winfield an important branch runs down nearly due south to the Gulf of Mexico at Galveston. A line from Albuquerque bisects the state of New Mexico, reaching the frontier of Mexico proper at El Paso on the Rio Grande, where it makes connection with the Mexican Central Railway Another branch from Barstow goes down to the lovely Californian sea-coast at Los Angeles, and thence along what is known as the Surf Line to San Diego; while yet another branch of first-class importance leaves the main line at La Junta, and twists its serpentine length up to Denver.

Apart from these more far-reaching branches, most of those worked by the Santa Fé are located in the State of Kansas, and may indeed almost be considered as radiating from Kansas City. Altogether the mileage operated by this great system amounts to 10,462. This includes trackage rights, or, as they are called in England, running powers, over about 150 miles of lines belonging to other companies. Such a mileage puts the Santa Fé system in the very forefront of the great railroad corporations of the new world.

The physical configuration is as interesting and on as vast a scale as its mileage. It has evoked what is perhaps the finest description of a railway journey in all literature. Readers of Kipling's *Captains Courageous* will remember the vivid account in that story of the trip of the special from Barstow to Chicago. From Chicago the line runs across more or less level but undulating prairie-land at an elevation of about 1000 feet above sea level. After crossing the Missouri at Kansas City it begins to rise steadily until it crosses the State boundary into Colorado at a little over 4000 feet. From here the real climbing starts as the track enters the Rockies. The highest summit on the system is reached at Raton Pass, near the border line between Colorado and New Mexico. Here the railway is more than 7500 feet above sea level. From this point westward there comes a succession of summits, on the whole each one lower than the one preceding, but entailing very heavy collar work for the locomotives in whichever direction they are travelling. From Seligman in Arizona the line drops rapidly until, at the Needles on the Arizona–California State Line, it is only 477 feet above the sea. From Seligman to the Needles is 149 miles, and in that distance the railway descends 4782 feet. This represents an average continuous grade of 1 in 162 against eastbound trains. But beyond the Needles there is yet worse, for in thirty-one miles the road climbs again 2098 feet to Goffs. This represents an average continuous grade of 1 in 77 against westbound traffic. Westward from Goffs the line falls again to Amboy at 810 feet; and thence rises to two crests, to 3819 feet at Summit and 3963 feet at Tehachapi. This last-named point represents the surmounting of the Cascade Range. From the westernmost summit of this final rampart the track falls to sea level at San Francisco Harbour.

Even a brief outline like the foregoing will perhaps enable the reader to visualize a little the stupendous engineering and traffic problems of

Among the Colorado Canons: The World's Biggest Locomotive—
Atchison, Topeka & Santa Fe Railway.

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the road. He can fill in to some extent a mental picture of the bridge and trestles, the grades and loops, the cañons and pinnacles, and he can form some conception of the locomotive problems involved in working through such a country.

But the problem for this railroad is economic as well as physical. In America freight traffic forms a far larger proportion of the whole than is the case in Great Britain ; and, as we have seen, the bulk of it has to be moved over single lines of railway. These considerations impose difficulties quite as urgent in their way as the physical ones due to the nature of the country traversed. Sometimes the resources of the companies are taxed to the utmost to handle all the traffic that is offered to them. Indeed, towards the end of the war the American roads were snowed under by the volume of freight waiting to be moved ; and the congestion was such that the whole trade of the country threatened to come to a standstill.

We shall perhaps get a better idea of the problem if we try to view it in a pictorial way. Think, then, of the Atchison's traffic in its various places of origin : the fruit gardens and orange groves of California ; the oil wells of New Mexico and Texas ; the cattle-ranches of Texas and Arizona ; the mines and quarries of the mountains, and the vast wheat-lands of Kansas, Missouri, Iowa and Illinois. We may picture to ourselves nearly every wayside depot as the spring from which flows a stream of freight larger or smaller, and we may think of the main line as a great river of traffic flowing steadily eastward.

The problem of the Transportation Department is to keep this stream of traffic moving, and to prevent it from stagnating in sidings and yards. Practically a freight car is only earning money while it is not only loaded but moving. Whenever it stands still it is not even paying for its keep. Therefore the problem of the Superintendent of Transportation is, first, how to get his freight cars to the end of their journey as quickly as possible ; secondly, how to have them loaded as fully as possible ; and thirdly, how to move them the shortest possible distance when empty so that they can get back to where they can be loaded again.

We must just glance at one more element in the problem that adds a yet further complexity to it. It is this. Not only is there this great volume of freight flowing eastward, but there is also a corresponding movement westward. Every loaded car that goes east must sooner or later return west. Much of this return mileage will unavoidably be empty, but a good deal also will be loaded mileage. This is all to the good so far as the revenue of the road is concerned; but it obviously adds to the complexity of the traffic problem involved, in that provision has to be made for the unloading of the car, and this will almost inevitably mean more or less delay. Then, too, there are other streams of traffic besides the main east and west flow. For instance, there is the line to Galveston, which is one of the great gulf ports of the United States. There is a big tonnage of freight passing through Galveston every year for shipment to Europe. Then further recall that amid all this freight movement the running of passenger trains, express and local, has to be provided for. We have now got some idea of the difficulties which confront the Santa Fé in arranging and co-ordinating all this movement of trains in both directions and at varying rates of speed over mostly single lines.

On the other hand, there are some factors which go to make the problem easier. For one thing, the great bulk of the goods traffic is "through," while the amount of "way" freight is by comparison small. In England the way freight, or station-to-station traffic, is greater in quantity than the through. This is still true, though the proportions of traffic are being very much altered by the rapid introduction of motor transport by road. The American railway business may be described as wholesale, the British as retail. Lastly, owing to the operation of various forces, freight rates have been forced down in America to what seems not inaptly described in picturesque Americanese as bed-rock. Indeed, in America as in other lands, there has been a tendency of late months for legislation to permit some slight increase of rates. Conditions have become too difficult even for the American railroads to tackle.

But at any rate for the past fifteen years American railways have applied a great deal of care and forethought to the consideration of the problems presented by their goods traffic. In the solution of these problems the locomotive designers and builders have worthily taken their full share of labour and responsibility, with the result that to-day American design and American methods have their influence upon railways all over the world, as I hope this present volume will show.

Apart from these economic factors in his favour, the American engineer has been helped much in another way. For the most part, especially out west, the railroad preceded the population. It thus came to pass that its building was not hampered by having to provide overhead bridges and such-like obstructions. Also, land being cheap, and often indeed given to the railroads in order that they might be induced to build in a particular locality, ample room was available for the track. This has resulted in a loading gauge far more liberal in its dimensions than in older countries such as Great Britain.

These various circumstances have given to the locomotive engineer in the States a much freer hand than his British brother has enjoyed; and therefore we need not be surprised to find engines in America of a size and power unknown anywhere else in the world. And of all the big railways with their big engines, the Santa Fé furnishes perhaps the most outstanding example. The policy of the line for many years has been in this direction. Thirteen years ago I chronicled the introduction of the 2-10-2 type with 4796 sq. ft. of heating surface. Mr. Player was the Master Mechanic of the road at that time, and, in common with most of the other engines built to his designs, these big freighters were planned as tandem compounds. In this type of locomotive, as its name implies, the cylinders were arranged in pairs end to end on either side of the engine. The high-pressure cylinder was usually placed in front of the low-pressure on the same side of the engine. A common piston-rod carried the two pistons, and there was only one crosshead and connecting rod on either side of the engine, just as in an ordinary simple-expansion locomotive. The 2-10-2 type is still being continued under Mr. Buck, but the tandem arrangement has been abandoned and most of his engines are built as simples. Other recent examples are consolidations for freight traffic and Pacifics for express passenger service. One important feature common to many of the more ordinary types of engine for the road, as well as to the exceptional class presently to be described, is the use of oil fuel. The immense deposits of petroleum oil which have been discovered in Texas, California and Mexico naturally attract the attention of all railroads going within easy reach of them. Oil is in many ways cheaper to handle, easier to burn, and more efficient as a fuel than coal, so it is not surprising that it is largely used wherever its price renders it possible. Combustion is so completely under control that neither smoke nor sparks need be emitted from the chimney. When a locomotive is at all forced some amount of sparking is almost inevitable with any kind of coal fire. Moreover, the dead weight of fuel to be carried is less with oil than with coal. One ton of good fuel oil is equivalent to from 1·72 to 2·76 tons of coal, according to the kind of coal used.

Ten years ago the Santa Fé had forty Mallet Compounds built by the Baldwin Locomotive Co. These were arranged as coal-burners.

But the 3000 class here illustrated are all planned to use oil fuel. The most remarkable feature of all these later engines, which was also introduced tentatively in two of the earlier ones, is the flexible boiler. After some experiments, the flexibility is now achieved by means of a kind of double ball joint. The rear portion consists of the firebox and boiler proper, while the forward section accommodates a superheater, re-heater, and feed-water heater. These engines are thus unique in that they combine both superheating and compounding. As a rule, locomotive engineers have seized upon superheating as a cheaper way of obtaining the efficiency associated with compounding, but these Santa Fé giants have it both ways.

The firebox measures 149$\frac{5}{8}$″ long by 78″ wide and 76″ deep. This immense firebox has a grate area of 80 sq. ft. and a heating service of 294·5 sq. ft. The boiler tubes afford a further 3625 sq. ft. of heating surface, making a total of 3919·5 sq. ft.

In the forward, or subsidiary, part of the boiler the superheater has a surface of 2318·4 sq. ft. There is also the re-heater, to be referred to again later, and the feed-water heater, which last has a heating surface of 2659·4 sq. ft.

As I have already implied, the engine is a Mallet Compound. The high-pressure cylinders driving the rear group of coupled wheels are 28″ in diameter with a stroke of 32″. The low-pressure cylinders have a similar stroke, but a diameter of 38″. The working pressure is 225 lb. per sq. in.

The driving wheels are 4′ 9″ in diameter, and the truck vessels 2′ 10$\frac{3}{4}$″. The engine is furnished with a 12-wheeled tender, which can carry 12,000 gallons of water and 4000 gallons of fuel oil.

Steam passes from the dome through the jointed pipes into the superheater, and from thence to the high-pressure cylinders. After being exhausted from these it is led through the re-heater to the low-pressure cylinders, and from them it is exhausted through the blast pipe in the ordinary way. The feed water is heated by the products of combustion passing through from the boiler proper.

On an experimental run this locomotive hauled a train of 100 freight cars, weighing in all 4341 tons, from Emporia to Argentine, 123 miles, in six hours twenty minutes. Emporia is just five miles west of Kansas City, and the maximum grade for this section is 21 feet per mile. In everyday service, these engines are at work in country where the ruling gradient is 90 feet per mile, equivalent to about 1 in 58. Over these mountainous districts they haul 1900 tons behind the tender at a speed of from 12 to 15 miles an hour. Others of the class are doing duty as pushers to assist trains over the Cajon Mountain in California, where the grade runs as high as 180 feet per mile, or about 1 in 30. Cajon lies between Barstow and San Bernardino on the Los Angeles branch. No. 3000 weighs in running order 308 tons, while the tender weighs 117 tons. The total weight of the locomotive is thus no less than 425 tons, and its length is 120′ 7½″ over all. They are veritable Goliaths in the land of locomotive giants.

NEW SOUTH WALES

From Spencer Street, Melbourne, to Sydney is 591 miles, and a very good inter-state express service is run to connect the two capitals. But unfortunately a break of gauge, is necessary at Albury, and a through train therefore is still in the future. The New South Wales lines are laid to the world's standard gauge, 4′ 8½″, while the Victoria Railways have a 5′ 3″ gauge. From Melbourne to Albury is 190 miles; while from the latter point to Sydney is 401. The express connections are therefore so arranged that the passenger spends the night on the New South Wales portion of the road, where he may, at least if he be a lucky first-class traveller, spend it in comfort. The limited express is allowed 11 hours 58 minutes for its 401 miles journey, which gives a journey speed of a little over 33 miles an hour throughout.

For such service Mr. E. E. Lucy, the Chief Mechanical Engineer, has designed some fine ten-wheelers of the kind reproduced here. There are several classes of ten-wheeled engines at work on the New South Wales lines, but these are the latest and biggest. The six coupled wheels measure 5′ 9″ in diameter. There are two outside cylinders with a bore of 22½″ and a stroke of 26″. Steam is supplied by a boiler of the straight-top type with a heating surface of 2752 sq. ft. The engine is built with a Belpaire firebox having a grate area of 30½ sq. ft. The boiler is fitted with a superheater of the Stirling pattern and an extended smokebox. What is rather an unusual feature in a modern locomotive is the use of the Stephenson link motion for actuating the steam valves. The New South Wales engines have already developed quite a distinctive appearance of their own. The plain business-like outline of our present example will give a sense of power and capacity for hard work, and the generous proportions of the boiler and the amount of heating surface provided will convince the student that such an impression is a just one.

The New South Wales railways had a total mileage of 5015¼ miles at the end of June 1920. They radiate from Sydney and Newcastle, the latter town being 104 miles north of the capital. The State is richly endowed with coal deposits, some of which are reckoned to be equal to the best seams of British coal. Copper, tin, silver and gold abound in the mountains, besides granite and marble. The eastern portion of the State is much the most thickly populated, and is also the most mountainous. A great mountain range runs from north to south parallel with the coast, and mostly at a distance of from 30 to 50 miles inland. Its peaks vary in height from 3000 to 6000 feet. Between the mountains and the sea the country is broken and diversified, and it is here that the bulk of the million and a half of people are settled. Beyond the mountains the level of the land descends generally with less rapidity. In some places the surface is well wooded, and in others covered with dense bush.

The railways, therefore, like those of South Africa, have a relatively steep climb inward from the coast; and the locomotive types which have been designed bear the impress of the physical geography of the district.

The Albury line, along which the inter-state traffic for Victoria passes, is the most important of the main lines. It reaches its summit at Exeter, which is 97 miles from Sydney and 2352 ft. above sea level.

The longest branch of the main line is that to Bourke on the banks of the Darling River. This point is 511 miles out of Sydney. At Valley Heights, 48 miles from Sydney, the line reaches an elevation of 1056 ft. From this station all trains are double-headed, and the line climbs up to Mount Victoria, 79 miles from Sydney, and 3424 ft. above the sea. The railway was originally laid out over these mountains in a series of switchbacks, but extensive re-surveying and re-grading has been carried out in recent years. Tunnels have been blasted and viaducts built, and a great many of the old switch-backs or zig-zags have been done away with. The Blue Mountains, as the great range is called hereabouts, are a favourite summer resort. The air is pure and bracing and the views are glorious, so it is little wonder that an enormous amount of traffic is handled in this section at holiday times.

Another branch that is going to have more than local importance one day is that which terminates at Trida, 467 miles nearly due west from Sydney. This line reaches its summit at Orange, 199 miles out of Sydney, and 2846 ft. up. Preparations are being made to build an extension of this line to Menindee on the Darling River. When this is completed a new through connection with Adelaide will be afforded.

The last section of the railways to which I need refer is that which

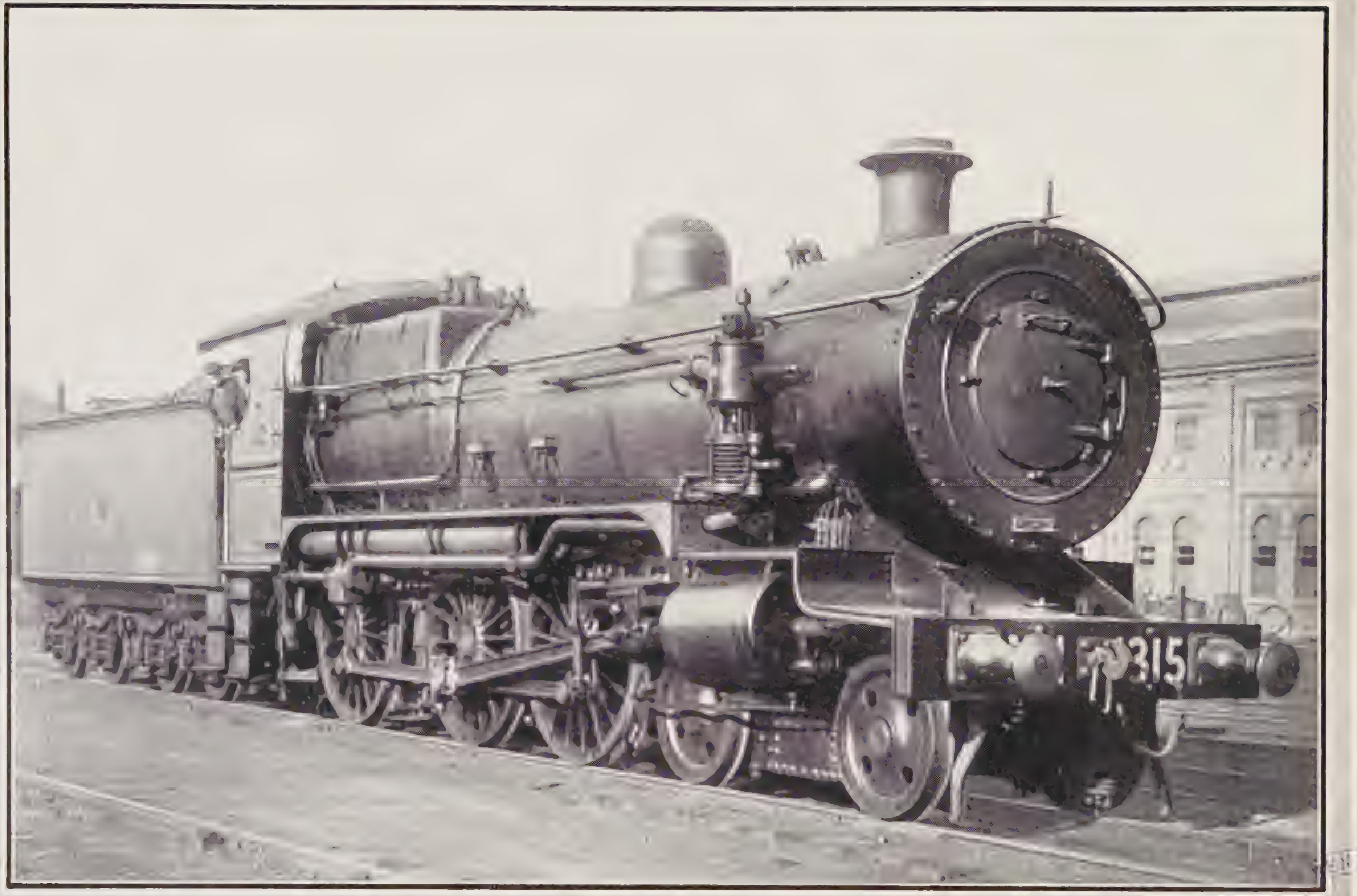

Photo by [illegible], New South Wales

Over the Blue Mountains:
A Handsome and Powerful Ten-wheeler for the New South Wales Government Railways

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connects with the Queensland Government system for Brisbane. The junction is at Wallan Garra, 492 miles from Sydney in a general northerly direction. The total distance to Brisbane is 715 miles. The best train leaves Sydney at 2.0 p.m. and reaches Wallan Garra at 8.40 a.m., which gives a running average of about 26 miles an hour. There is a wait of 50 minutes at Wallan Garra, and the inevitable changing due to the break of gauge. Then the Queensland train leaves at 9.30 a.m. and arrives at Brisbane at 6.40 p.m. This works out at an average for this part of the journey of 24 miles an hour.

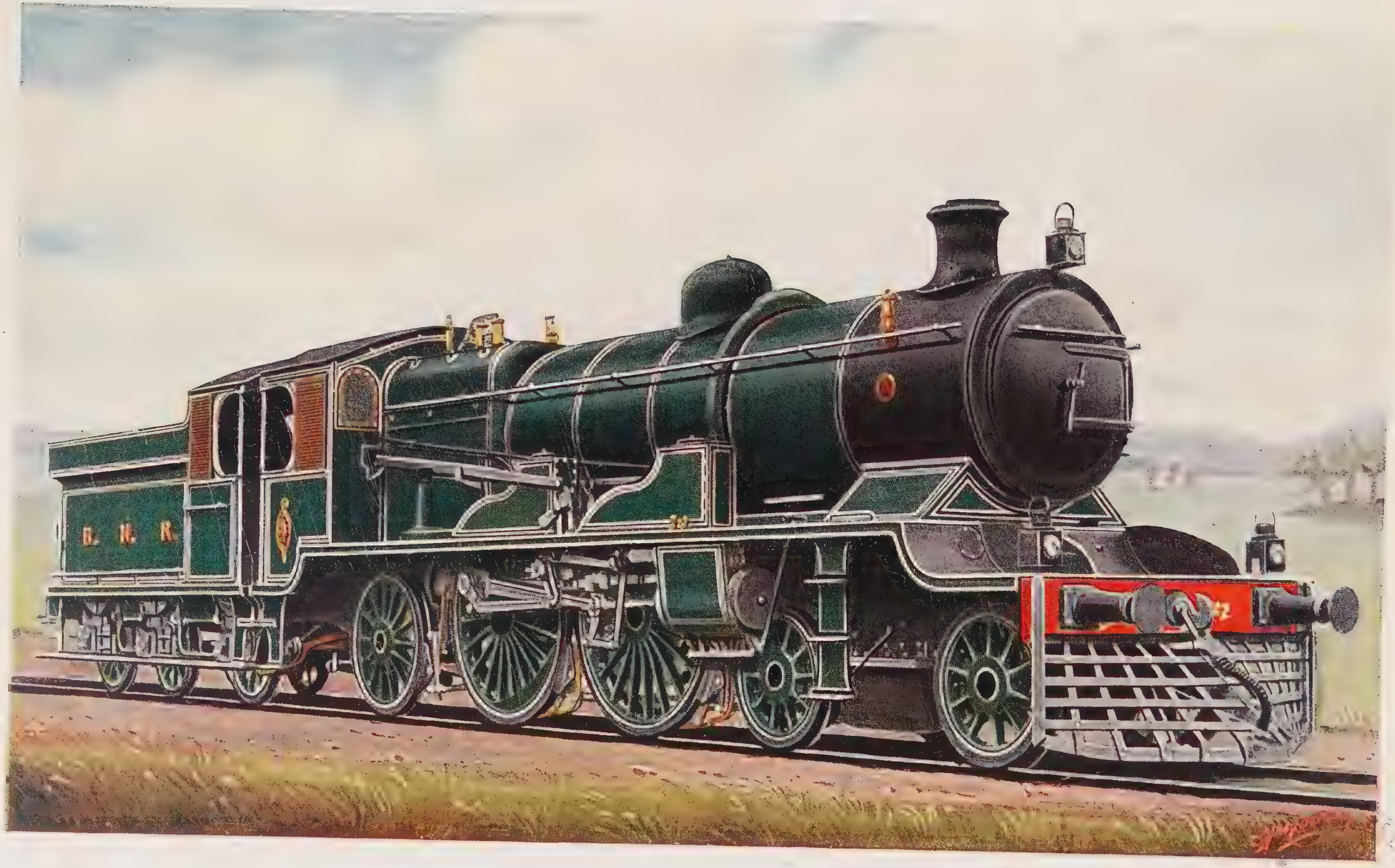
There is a great shortage of skilled labour in New South Wales, and the difficulties arising from this have led to the adoption of many labour-saving devices on the locomotives of the Government railway. Mr. Lucy, the Chief Mechanical Engineer, who was formerly on the Great Western Railway at their Wolverhampton shops, has arranged some of his engines experimentally with a view to economy of labour. The special equipment includes smokebox ash-ejector, and rocker-bar grates with hopper ashpan, which may be flooded and the ashes quenched with hot water. The ashpan has hopper slides operated by steam, thus doing away with the need for raking the fire. Axle-boxes are lubricated both at top and bottom. The coal plates of the tender are shaped so that the coal automatically falls towards the fireman. A trial trip was carried out about two years ago from Sydney to Wallan Garra and back. The engine used was No. 1353, one of the class illustrated in the present article, and the whole 1000 miles was accomplished without any shed attention. All the labour involved, beyond that of the three engine crews, being comprised in taking coal twice on the journey. The trial involved 20 miles of 1 in 40 grade outward and 18 miles of similar grade homeward bound, the summit being 4473 feet above sea level at Ben Lomond, 401 miles from Sydney. The terminus at Wallan Garra is 2875 feet above sea level.

It only remains to add that these engines, in spite of their small driving wheels, can attain a speed of 70 miles an hour, and they can haul as much as 1800 tons on the level or 300 tons on a gradient of one in forty.

BENGAL-NAGPUR RAILWAY

THE main line of this railway runs from Howrah, which bears about the same relation to Calcutta as Southwark does to London, in a general south-westerly direction, dividing into two almost equally important sections. One line runs more or less due south-west along the coast of the Bay of Bengal, forming, with the Madras Railway, a direct route between Calcutta and Madras. The Bengal–Nagpur line passes through Balasore, Cuttack, Vizagapatam, and Waltair, at which last place is the actual junction with the Madras Railway. The other main-line section goes off in a westerly direction, passing through Sambalpur, Raipur, and Nagpur, at which last place it forms a junction with the Great Indian Peninsular Railway, its partner in a through route from Calcutta to Bombay. Through expresses run daily between the terminal points on both these lines. These trains are formed of exceedingly luxurious cars for European passengers, providing also accommodation for native passengers of various races. The trains are lighted throughout with gas. The through journey between Calcutta and Madras occupies 43 hours, while that from Calcutta to Bombay takes 46 hours and 16 minutes. Like most of the large Indian railways, the Bengal–Nagpur consists of lines laid to different gauges. The main lines are broad gauge, 5 ft. 6 in., but there is also a considerable mileage of 2 ft. 6 in. gauge line. In common with other Indian railways during the last few years, great strides have been made in the locomotive and carriage department, and the new rolling stock will compare favourably with any used in England, although not even yet have the Indian lines begun to take full advantage of their broad gauge. Whether such advantage ever will be taken is one of the questions of the future. There can be little doubt that some day the Indian railway system will be linked up with lines advancing from the west through Persia and Afghanistan, and, when that day comes, India will feel acutely the waste of capital and he inconvenience caused by her present chaotic system of varied gauges. If narrow-gauge lines are an absolute necessity in out-of-the-way mountainous districts, it does at least seem a pity that the Indian standard gauge should not be conformed to the world's standard at the earliest possible opportunity. The longer the conversion is put off the greater will be the expense of it when it does come. Meanwhile, if India is to really take advantage of the broad gauge which has been adopted for her main line it ought to have engines proportionately larger than those in use in standard-gauge countries, such as America. With all the improvement which has recently taken place the American standard of size has not yet been reached, and probably is not yet required in spite of the growing length and weight of trains, both goods and passenger. Meanwhile the extra 9½ inches of gauge are valuable in this way, that they enable the locomotive engineer to have a little more room at his disposal in arranging his engine.

The engine illustrated in our picture is one of the latest types to be put into service in India. It is a four-cylinder De Glehn compound "Atlantic," and is, in all essential features, a reproduction of the famous express engines which have created such a reputation for themselves and their designer, not only in France, the country of their origin, but also in Germany, Great Britain and America. This engine has a boiler measuring 5ft. 1¼ in. in diameter, by 14 ft. 9 in. long between tube plates; in this boiler are fitted 195 tubes, each with a diameter of 2¼ in., and providing a total heating surface of 1746 sq. ft. The firebox has a grate area of 31·7 sq. ft. and provides an additional heating surface of 153 sq. ft., the total heating surface thus amounting to 1895 sq. ft. The firebox is of a modified Belpaire type, and the boiler is equipped with the ordinary Ramsbottom safety valves set to blow off at a pressure of 220 lb. per sq. in. The engine, though quite modern in design, is not a large one as is understood by that term in locomotive building to-day. Indeed, the boiler provides somewhat less nominal heating surface than the "Atlantic" compound for the standard-gauge Great Central Railway, in spite of the engine having been built for the Indian broad gauge. As usual in the De Glehn compound, the high-pressure cylinders are placed outside. These measure 13 in. in diameter with a stroke of 26 in., the low-pressure cylinders inside being 21½ in. in diameter, also with a stroke of 26 in. As usual, the high-pressure cylinders are arranged to drive the trailing pair of driving wheels, while the inside cylinders drive on to the leading crank axle. The valve gear is of the now favourite Walschaert type. The driving wheels measure 6 ft. 6 in. in diameter, the bogie wheels 3 ft. 7 in., and the trailing wheels 4 ft. 8½ in.; all the



In Clive's Footsteps: De Glehn "Atlantic," Bengal-Nagpur Railway.

wheels of the engine have inside bearings. The total weight of the engine amounts to 74 tons 3 cwt., of which 34 tons 10 cwt. are carried on the coupled drivers. The tender weighs another 40 tons 5 cwt. in working order, and having on board 3500 gallons of water and 6 tons of coal. A roomy cab is provided both on engine and tender, measuring about 9 ft. wide over all. The two cabs overlap to a certain extent, the roof of the engine cab being carried over and slightly raised to clear that of the cab on the tender. Louvred shutters are provided on both cabs, which may be drawn to exclude the sun while still admitting the breeze created as the locomotive sweeps along. A special word of praise must be given to the complete provision for the engine men afforded by the design of this cab. The following little table will be of interest as exhibiting at a glance the variations in size of De Glehn compounds adopted in various countries.

	PENNSYLVANIA	NORD	GREAT WESTERN	BENGAL-NAGPUR
Type	Atlantic	Atlantic	Atlantic	Atlantic
Driving wheels	$6' 8''$	$6' 8\frac{1}{2}''$	$6' 8\frac{1}{4}''$	$6' 6'$
Cylinders, high pressure . .	$\left.\begin{matrix}14\frac{3}{16}\\23\frac{5}{8}\end{matrix}\right\}\times 25\frac{3}{16}$	$\left.\begin{matrix}13\frac{1}{2}\\22\end{matrix}\right\}\times 25\frac{1}{4}$	$\left.\begin{matrix}13\frac{3}{8}\\22\frac{1}{16}\end{matrix}\right\}\times 25\frac{3}{16}$	$\left.\begin{matrix}13\\21\frac{1}{2}\end{matrix}\right\}\times 26$
,, low pressure . .				
Boiler, diameter . . .	$4' 11''$	$4' 9\frac{1}{4}''$	$4' 9\frac{5}{16}''$	$5' 1\frac{1}{4}''$
,, number of tubes . .	139 *	126 *	126 *	195
,, diameter of tubes . .	$2\frac{9}{16}''$	$2\frac{3}{4}''$	$2\frac{3}{16}''$	$2\frac{1}{4}''$
Total heating surface . .	2616·8 sq. ft.	2275 sq. ft.	2325 sq. ft.	1899 sq. ft.
Working pressure . . .	227 lb.	228 lb.	227 lb.	220 lb.
Gauge of track . . .	$4' 8\frac{1}{2}''$	$4' 8\frac{1}{2}''$	$4' 8\frac{1}{2}''$	$5' 6''$

* Serve tubes, providing nearly double the nominal heating surface of the ordinary smooth-bore tube.

Just recently Mr. Carr, the Chief Mechanical Engineer, has introduced new express engines of the 4-6-0 type. These are simple expansion superheaters. The driving wheels are 6 ft. 1 in. in diameter. The cylinders measure $21\frac{1}{2} \times 26$ in. The firebox has a grate area of 32 sq. ft. and a heating surface of 163 sq. ft. The tubes contribute a further 1096 sq. ft., making a total of 1259 sq. ft.; while the superheating surface is 250 sq. ft. The working pressure is reduced to 160 lb. Compared with the 220 lb. of the compound engine illustrated in the present article, this gives some idea of the saving in wear and tear of the boiler effected by the introduction of superheated steam.

GREAT INDIAN PENINSULA RAILWAY

This is one of the big railways of India, having a total mileage of 3322·44 including narrow-gauge lines.

Its headquarters are at Bombay, and it operates a considerable suburban traffic in the Bombay district. From here the main line branches out in four chief directions. One line runs south-east to Raichur, a distance of 443 miles. Here a junction is made with the Madras and Southern Mahratta Railway for various points in South India. Another line runs nearly due north to Agra, 835 miles, and Delhi 957 miles. Over this section runs the Punjab mail, booked to do the trip in exactly 34 hours, giving an inclusive running speed of 28 miles an hour. Between these two lines lie two others, both going in an easterly direction. One runs due north-east, bifurcating to Balharshah on the Hyderabad border, and to Nagpur, where connection is made with the Bengal–Nagpur Railway.

The last of the four divisions of the main line runs about north-east to Jubbulpore, 617 miles. Here connection is made with the East Indian Railway for Allahabad.

The Great Indian Peninsula has always been distinguished by its up-to-date locomotive stock, and the new engines of the class illustrated here are, at the moment of writing, the largest ever put into service in India. One remarkable feature of the Great Indian Peninsula line is that afforded by the crossing of the ghats. The ghats are mountain ranges running more or less parallel with the sea-coast, and to get away from the coast the railway has to climb these mountains. There are two of these ghats: the Thull Ghat, 10 miles long, and the Bhore Ghat, 16 miles. The steepest portion of both these lines is at 1 in 37. The lines are laid out as switchbacks, and special banking engines are employed to help trains up.

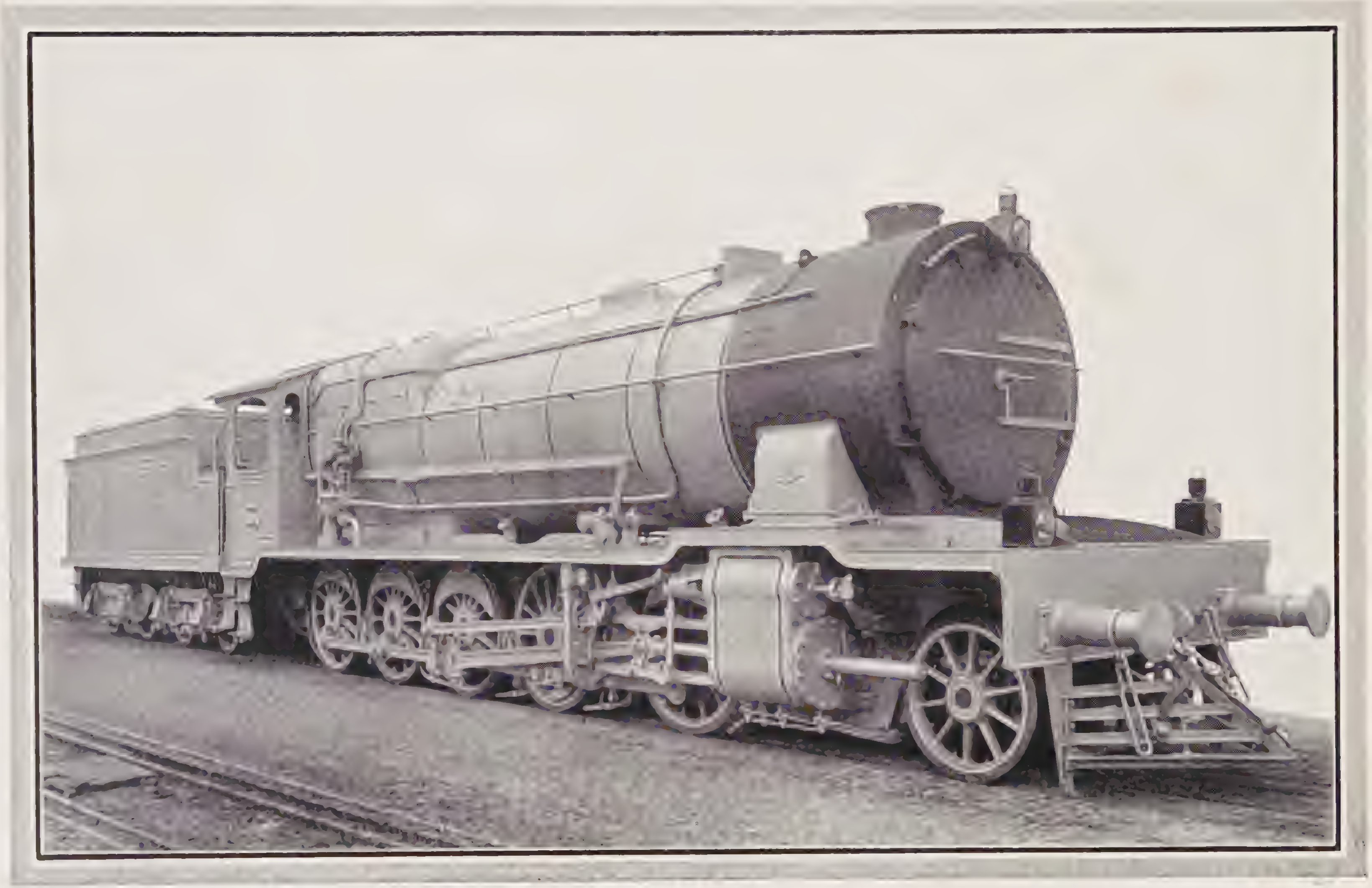
The Thull Ghat lies between Kasara and Igatpuri, and has 4½ miles of maximum grade. The booked time for the Calcutta mail over the

Thull is 42 minutes for the ten miles. The new engines will haul a load of 1000 tons on this section, and as much as 1600 tons over other sections of the line with a ruling grade of 1 in 150.

As will be seen from the illustration, they are of the 2-10-0 or decapod type. The boiler is 16′ 4″ long with a diameter of 7′ 1¼″ outside the lagging. The tube heating surface amounts to 1914 sq. ft. To this, 36 flues of 5¼″ diameter add another 824 sq. ft. The superheater gives 617 sq. ft. of superheating surface in addition, while the Belpaire firebox provides 230 sq. ft. The total heating service is thus no less than 3585 sq. ft. Oil fuel is used. The tender provides for the carriage of nine tons of fuel oil and 5000 gallons of water. Steam from this huge boiler is used in four simple cylinders, each of 20 inches diameter, with a stroke of 26 inches. The motion consists of two sets of Walschaert valve-gear.

The driving wheels are 4′ 8½″ in diameter, and the pony wheels 3′ 7″. The third and fourth pair of drivers are flangeless. The over-all length of engine and tender is 70′ 5″, and the combined weight in working order 174·43 tons.

So far, thirty of these magnificent locomotives have been built by the North British Locomotive Co. at their Hyde Park Works, Glasgow. We are indebted to the builders for the photograph which is reproduced herewith.



Over the Ghats: A big "Decapod" for the Great Indian Peninsula Railway

PEKIN-KALGAN RAILWAY

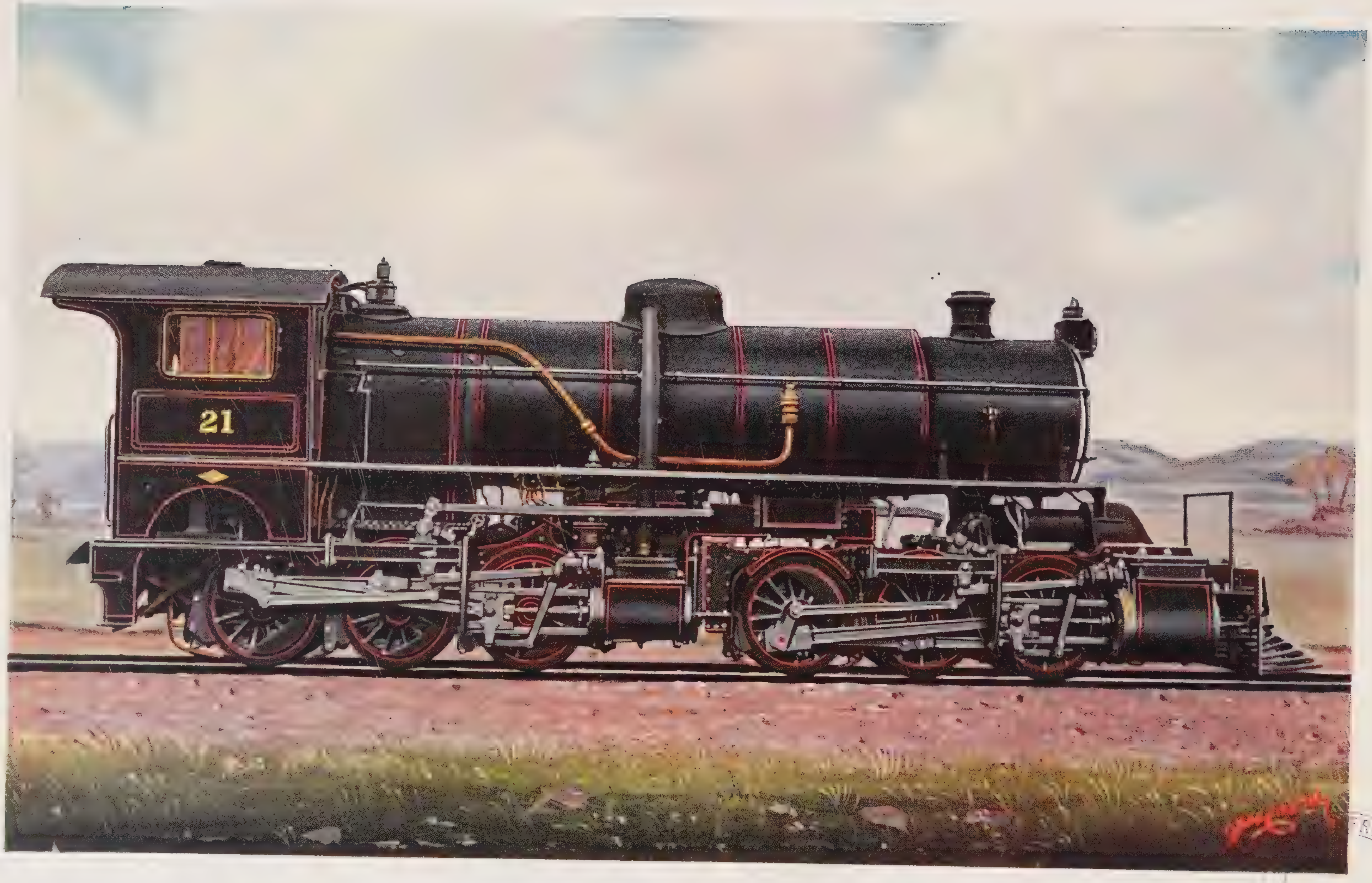
To those of my readers who have read the Rev. James Gilmour's fascinating book, *Among the Mongols*, the title of this railway will come as something of a shock. The great missionary's vivid descriptions of travel in and around the north-western outposts of China seems so incongruous with the idea of railways, and his accounts of overturned bullock carts and the other unpleasant incidents of primitive travel present such utter contrasts with our Western notions of the safety and comfort of a passenger train, that it is hard to realize that it is only just 51 years since he first left Pekin for the north. Kalgan, though it bears a Mongol name russianized, is really in China, and the Chinese call it Chang Chia K'ou, the pass of the Changs. The town is situated a few miles inside the Great Wall, and hence arose the Mongol name Halga, or the Gate, russianized into Kalgan.

From Pekin the distance traversed by the railway is 125 miles, and as Kalgan is perched among the great mountain ridges of the Khingan Range there is a good deal of very heavy grading. The worst place on the line is at the Nankow Pass, where a stretch of 12 miles at 1 in 30 has to be encountered. These features of the road explain the adoption of the type of locomotive shown in our picture. Heavy grades and sharp curves are usually closely associated, and, in the case of this line, it was necessary to provide an engine which should be capable of negotiating steep hills on curves of only 500 feet radius with heavy loads. Three engines of the type illustrated in our picture have been built by the North British Locomotive Company for the new line.

These engines are what is known as Mallet Articulated Compounds. M. Mallet designed a system of compounding for locomotives which was first adopted in some little tank-engines built at Creusot Works in 1876 for the Bordeaux and Biarritz Railway, now part of the Midi. These first Mallet Compounds had only two cylinders and were arranged as front-coupled six-wheeled side-tanks. The special feature in recent developments of this type of compounding has been the adoption of the plan of an articulation of the wheel base. Essentially this is much the same as the idea of the steam bogie as tried in England by Fairlie. In these articulated engines there is a leading bogie, as in the ordinary English or American express passenger locomotive, but all the wheels, both those arranged in the bogie and those in the main frames of the engine, are of the same size and all are drivers. For some years past now this type has been growing in favour whenever there has been very heavy pulling at slow speed to be done. Some fine engines on this plan have been put into service on the Bavarian State Railways and other European roads, and these proved so satisfactory that the type was taken across the Atlantic and first appeared in its americanized form in the large 0-6-6-0 freight engine built by the American Locomotive Company in 1904 for the Baltimore and Ohio Railroad.

Since then several articulated locomotives have been built for heavy mountain freight service on United States roads, and American builders have recently been busy on engines of this class for French railways. The newest development in the direction of the adoption of this pattern of engine is in a large passenger locomotive for the Atchison Topeka and Santa Fé. In this last engine, as well as in some of the goods engines lately put to work, small pony trucks are fitted, either at the leading end or at both ends. The necessity for, and usefulness of, this addition seems to be a disputed point, at any rate with the small driving wheels of a freight engine.

The locomotive in our picture is arranged, like the large Baltimore and Ohio engine, with a wheel plan as represented by the formula 0-6-6-0. This means that there are two groups of six-coupled drivers, with no leading or trailing carrying wheels. The high-pressure cylinders, as usual in engines of this pattern, drive the rear group of coupled wheels and are bolted to the main frames. The low-pressure cylinders are forward, and drive the coupled wheels of the steam bogie. Both sets of cylinders are placed outside their respective frames, as will be seen from our picture, and both are actuated by Walschaert valve-gear. A feature of the valve-gear of these engines is that the corresponding parts of gears are interchangeable. That means, for example, that the radius rod is the same, whether it be for high- or low-pressure cylinders. The high-pressure cylinders are 18″ and the low-pressure 28¾″ in diameter, both sets having a stroke of 28″. The slide valves are of the Richardson type for both high- and low-pressure steam chests. As I have explained in more detail in the *Boy's Book of Locomotives*, this pattern of valve seeks to reduce the load of steam pressure under which the valve has to be moved,



Among the Mongols: Mallet Compound for Service in the Khingan Mountains, Pekin=Kalgan Railway.

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and is what is known as a balanced valve. In most of the large compounds built in America the high-pressure cylinders have been equipped with piston valves, the Richardson type being used only with the low pressure.

As the cylinders driving the front group of wheels are bolted to the bogie frames, instead of to the main engine frames, it is obvious that some means must be devised to make a flexible connection for the steam pipe through which these low-pressure cylinders are to be fed. This is done by means of a ball-and-socket joint at the rear end of the connecting pipe, while the front end forms a sort of telescope with the steam chest of the low-pressure cylinders. In order to provide additional power when required, as, for instance, at starting, an auxiliary valve is fitted by which the driver can admit a certain amount of live steam, that is, steam at boiler pressure, direct to the low-pressure receiver.

Steam is supplied by means of a large boiler having a heating surface of 2591 sq. ft. and a working pressure of 200 lb. per sq. in. The firebox has a grate area of 45·1 sq. ft.; the wheels, all of which are utilized for driving, are 4′ 3″ in diameter, and the wheel base of each bogie is 9′ 8″. The total weight of the engine in working order, without the tender, is 96 tons, while, owing to the arrangement of the wheel base on this articulated plan, the weight on each axle is only 12 tons. The tenders have been built in the road's own workshops. These engines are fitted with steam reversing gear and Westinghouse brakes. A cow-catcher is added at the leading end, and the bitter winters of North China necessitate the provision of a comfortable closed-in cab.

It is interesting to note that the Pekin–Kalgan railway is being built by the Chinese Government itself out of the surplus profits of the line between Pekin, Tientsin and Mukden. It is being built by Chinese workmen under a Chinese engineer, Mr. Jeme Tien Yow, who was educated in America and who received his practical training under Mr. Kimber, the engineer of the Pekin-Mukden line.

Even in Mr. Gilmour's time, Kalgan was a busy place. It is the collecting point for the large quantities of tea, which every year, in the form of bricks, are taken across the dreary Gobi by caravans of Mongol wagons and camels. From Kalgan, too, the wandering Mongols obtain all they need from civilization—farinaceous food-stuffs, cotton fabrics, Chinese silks, saddles, crockery, ironmongery, needles, buttons, matches. Kalgan has been in the past the mart for all this interchange between civilized China and the descendants of the men who, seven centuries ago, were following Genghis Khan on his career of conquest. There thus seems to be a large freight traffic ready for the line as soon as it shall be completed, a traffic which should be efficiently and economically handled by the engines shown in our picture.

MIDLAND RAILWAY

THE Midland is the third railway in England in respect of its mileage. Its main lines fall into three chief geographical divisions. These are: (1) From London to Leeds; (2) from Bristol to Manchester; (3) from Leeds to Carlisle. These three sections coalesce in a tangle of junctions and connecting lines. This junction area roughly covers a parallelogram the four corners of which lie at Derby and Sheffield in the west and Nottingham and Leeds in the east.

A map of the system has a queer resemblance to the arterial chart of the human body. It has two legs terminating respectively at London and Bristol, while the head is 300 miles away at Carlisle. And the red of its passenger rolling-stock might be supposed to lend sanction to the notion. Yet, after all, the true life-blood of the Midland is not red at all, but black, for the Midland is one of the great coal lines of England, and its revenue largely comes from the long trains of black diamonds ceaselessly rolling south and south-west and north-west along these tracks.

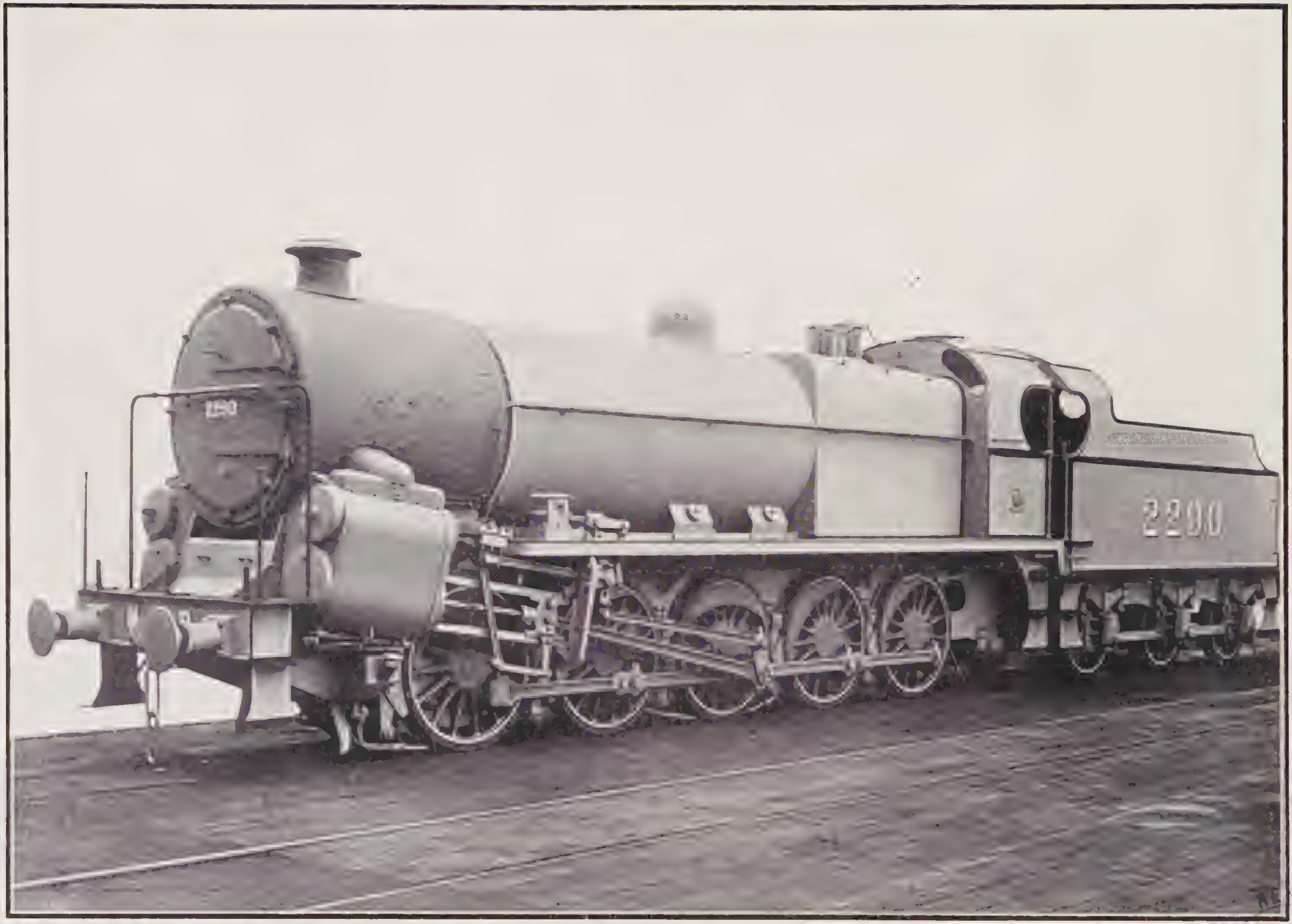
This is the real reason of the tangle of lines scattered thickly through the central area of the country, for these lines provide outlets for the traffic originating in the great central coal regions. The South Yorkshire, the Nottinghamshire and the Staffordshire coalfields are all served by the railway; and in spite of the fact that it reaches the sea at four points, its title is a thoroughly appropriate one.

The geographical position of the Midland carries with it the implication of a good deal of hard work, and that implication is very fully justified. Compared with its principal neighbours and erstwhile competitors, the Great Northern on the east and the London and North-Western on the west of it, the lines of the Midland have fallen in hilly places. Even along its main line to London, through the quiet and pleasant scenery of the shires, there is a good deal of heavy locomotive work to be done. To the north the line to Carlisle and Scotland climbs along nearly the whole length of the Pennines; while the Bristol line comprises in its length the famous Lickey, of which more anon.

It might have been thought that in these circumstances the locomotives of the Midland would exhibit marked traces of the geographical and physical influences of the line. It is therefore the more surprising to find that this is by no means the case. True, its goods engines are now being equipped with newer and larger boilers, many of which are fitted with superheaters; but for the most part they still conform to the old-fashioned 0-6-0 type which has been since the days of Stephenson the standard British pattern for this class of engine. Other British "heavy" lines have long since employed large numbers of eight-coupled coal engines, but not the Midland. Similarly with its passenger stock. The standard Midland express engine to-day is still the 4-4-0. The boilers are bigger, the Belpaire firebox has been introduced; in a few cases compounding has been tried; but in general type the Midland express engine remains what it was forty years ago when Samuel Johnson reigned at Derby.

If it should be asked how then does the road manage to move its teeming traffic on these heavy grades, the answer is in two words: Double heading. Thirty years ago the late Professor Foxwell noted that the Midland was more addicted to the use of two engines for one train than any other line in Great Britain, and I imagine the same thing is true to-day. Sometimes this double heading takes a form almost grotesque, as, for instance, when you see a coal train being hauled by a new large six-coupled engine with one of the old single bogie express engines acting as pilot. On passenger service piloting is not so common as it once was. The newer eight-wheeled engines are generally left to do their work by themselves, though even now I believe the use of two engines is by no means infrequent. One cannot help wondering when the Midland is going to get into line with the other railways in the types of locomotive employed in this service.

Closely allied to this subject of piloting, or double heading as they call it in America, and yet distinct from it, is the matter of banking. In railway parlance, banking means the employment of a helping engine at specially difficult parts of the trip. It differs thus from double heading, which means using a helping engine all the way. Double heading in the ordinary work of a road is a kind of locomotive heresy, but banking is an unavoidable necessity in places where steep or long grades have to be encountered. One such locality within the territory of the Midland Railway is known as the Lickey incline. The south-western limb of the Midland stretches from Derby through Birmingham



Up the Lickey: A "Decapod" Pusher for the Midland Railway
(now part of the London, Midland & Scottish system)

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and the Black Country to Bristol. Indeed, its ramifications are more extensive, for five miles out of Bristol, at Mangotsfield, a line branches off to Bath, and at this point connection is made through the Somerset and Dorset Railway with Templecombe and Bournemouth.

This last-mentioned place is exactly 280 miles from Leeds via the Midland Railway and Derby, and so 392½ miles from Carlisle and the Midland Scottish connections. The Somerset and Dorset Railway belongs jointly to the Midland and the London and South-Western. Its locomotive and carriage stock bears the impress of Derby very strongly. Its locomotive stock is all Midland in design, though distinct from that of the parent line by being painted a royal blue. Another joint line in which the Midland is interested is the old Eastern and Midlands, now known as the Midland and Great Northern. In this case the locomotives and rolling-stock partake of the character of both the owning companies, and new locomotives are built at the separate works at Melton Constable, though apparently the plans and drawings of the latest engines come from Derby. The appearance of the same design in the three colours, red, yellow (for the Midland and Great Northern Joint) and royal blue, makes quite a striking combination.

But in one respect the Somerset and Dorset, though a subsidiary line, has brought about a notable innovation in the practice of Derby. That was in the production of a very handsome eight-wheels coupled engine of the consolidation type. The Somerset and Dorset passes through the Cheddar district, and Cheddar is famous for coal as well as cheeses. Indeed, to the railway engineer I suspect that the former bulks the more largely of the two. Anyway, curiously enough, it was in this far-away south-western corner of the territory that this first Midland locomotive innovation appeared; and now, in connection with the same geographical region, comes the second novelty, which is the true subject of this chapter.

What I have already said will prepare the reader to suspect the importance of that whole south-western division of the Midland Company's lines. Up from Bristol to Birmingham flows not only the traffic originating in the docks and manufactories of Bristol and the stone quarries of the Mendips, but also the passenger traffic between Bournemouth and the busy industrial centres of the Midlands and the North. Further, Bristol is the chief point in the interchange of traffic with the Great Western from Exeter and Plymouth and the West of England. It will readily be seen, therefore, how important a part of the railway communications of the British Isles is furnished by this section of the Midland main line. And there, right in the path of all this traffic and barring the road to the north, stands the Lickey. It is situated between Blackwell and Bromsgrove. It is about two miles in length, and opposes a continuous gradient of 1 in 37·7 against north-bound traffic; while beyond the worst part of the grade are approaches, both north and south, which are also difficult. When the line was first planned objection was raised to the permission of such a severe gradient, and it was predicted that no ordinary smooth-wheeled locomotives would be able to work trains over it. But Captain Moorsom, the engineer for the line, had been trained in the States, where such conditions of working were by no means unknown, and he said that if English engines could not do the work, American could. And, in fact, the first locomotives used on the Lickey incline were eight single-driver engines with leading four-wheeled bogies. They were built by the celebrated Philadelphia firm of Norris and Co. These engines are reputed to have hauled a train weighing 33 tons up the incline at a speed of 12 to 15 miles an hour, and to have hauled a maximum load of 53½ tons at 8½ miles an hour.

But of course these were really small trains even for those early days, and very soon it became the established rule of the road that all trains were to be assisted up the Lickey. For this banking service some front coupled bogie tank-engines have been employed to help passenger trains for a long time. These engines were originally built for the London suburban services. On goods trains ordinarily six-coupled goods-engines were used, and lately it had become the custom to use two or three coupled together as pushers, with the regular train-engine on ahead. Three engines to one train was, however, too much even for the Midland, and the latest attempt to solve the problem is in the fine engine illustrated in this article.

This engine is the only ten-wheels coupled tender-engine in use in Great Britain to-day. The wheels are all 4 ft. 7½ in. in diameter. There are four cylinders, two inside and two outside. The engine is arranged as a simple, all the cylinders being of the same dimensions and all taking live steam from the boiler. The cylinders are 16¾ in. in diameter by 28 in. stroke. They are so arranged that one valve of the piston type serves two cylinders. The utmost simplicity of construction has thus been aimed at. The valve-gear is a very neat example of the Walschaert type. Steam at 190 lb. pressure is supplied from a boiler

14 ft. long and 5 ft. 3 in. in diameter. There is a total heating surface of 1718·25 sq. ft. made up of 158·25 sq. ft. in the firebox and 1560 sq. ft. in the tubes. The superheater is of the Midland Company's own type. It consists of twenty-seven elements, and gives a total superheating surface of 445 sq. ft. The engine weighs 73 tons 13 cwt. 1 qr. in working order, and the maximum axle-load is 15½ tons. This is on the centre pair of wheels, on to which all the four cylinders drive. For such an intermittent service as banking, with frequent opportunities for replenishing food and water, very moderate tender accommodation is all that is necessary. The one provided in this case only weighs just over 31½ tons, and carries 4 tons of coal and 2050 gallons of water.

For some time past the Midland has been fitting its goods-engines with a large, and it must be confessed rather ugly, shelter attached to the tender. This has been in order to mitigate the severity of the exposure for the crews when engaged in shunting or banking service. These services always involve a lot of backwards running. In No. 2290, however, the commodious shelter has been very neatly designed to harmonize well with the general contour of the tender and locomotive, and the crew ought to be able to do its work in comfort even when the south-westerly gales are sweeping up from the Bristol Channel, or chill down from the mountains of Wales.

In this very interesting example of locomotive design Sir Henry Fowler has shown us how he can break away from the ruck of the commonplace. It remains to watch with much interest to see what new forms his genius will produce for the ordinary main-line goods and passenger services of the road.

CANADIAN PACIFIC RAILWAY

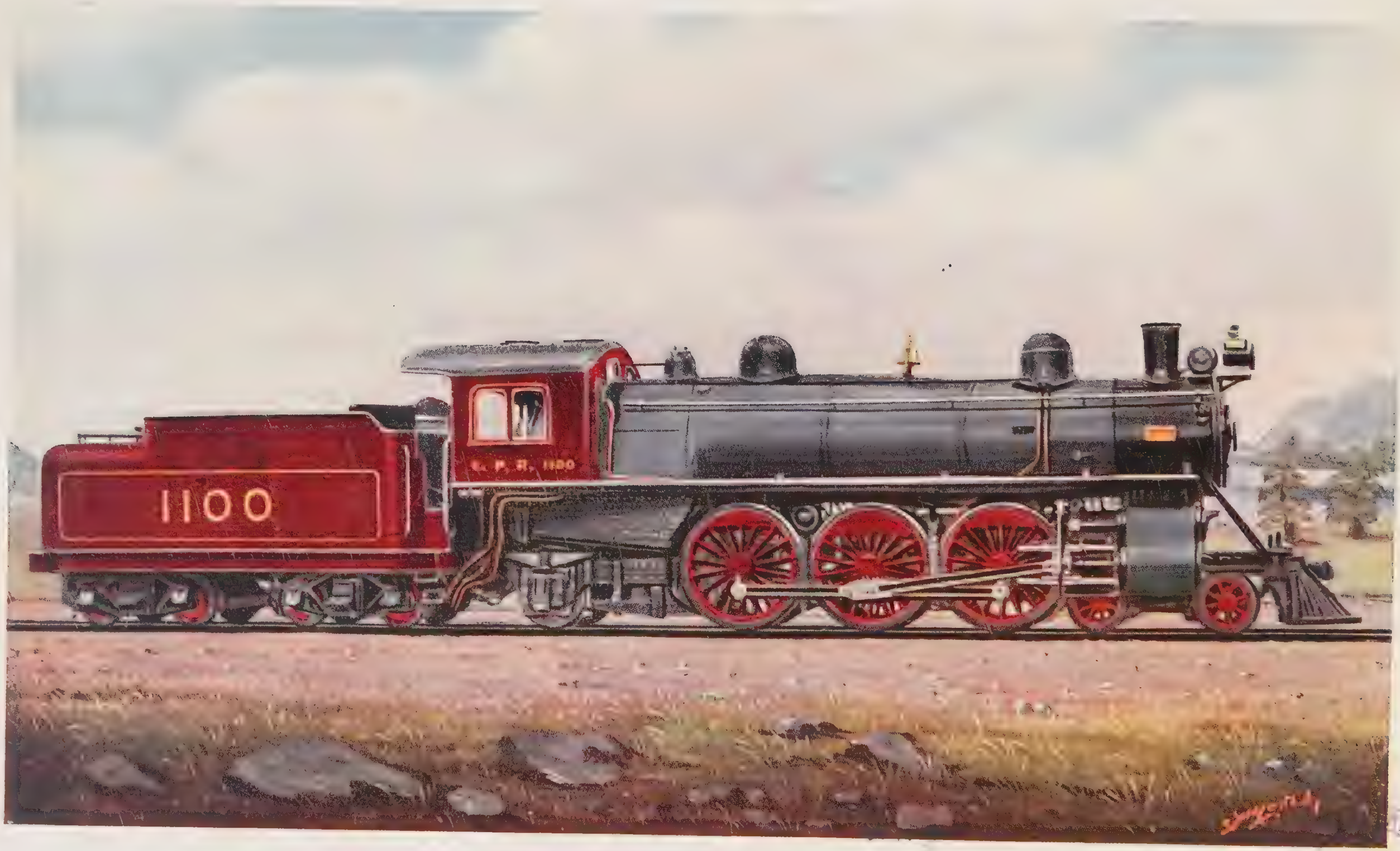
THE Canadian Pacific is one of the greatest and most fascinating Joint Stock Corporations in the whole world. It began business in 1888 under a charter of the Canadian Government, by which it was allowed ten years for the completion of a complete transcontinental road. About 450 miles of the line had already been built under Government auspices stretching from Montreal up to the Ottawa Valley. This line was handed over to the new Company, and the construction of the remaining 2500 miles proceeded with so rapidly that in less than half the time allowed by the charter the road was opened right through from Montreal to the Pacific Coast at Vancouver, and trains running. The Canadian Pacific was thus the first line right through from Atlantic to Pacific owned by one Company and under one management. The building of the road proceeded at the rate of more than two and a half miles every day, a record which is the more wonderful seeing that a good part of the country through which the road was being pushed was an unknown land; the railway company's engineers over large districts of Central and Western Canada were the first systematic explorers.

The most difficult portions of the work were encountered in the country round Lake Superior and in crossing the great ranges of mountains which divide the western prairies from the Pacific Coast. Round Lake Superior the road had for the most part to be blasted out of the solid rock, and to-day, as you skirt in your sleeping car the northern coast of this great inland sea, you look down from the car window in many places almost sheer into the water beneath. The most noteworthy engineering feat in crossing the mountains is perhaps the famous spiral descent into the valley of the Fraser River at Kamloops. The first through passenger train left Montreal on the 28th June, 1886. There are now two through trains starting daily from either terminus. The west-bound trains are the Imperial Limited, which leaves Montreal at 9.40 every morning, and the Pacific Express, which leaves at the same hour every evening. East-bound the Imperial Limited leaves Vancouver at 8 o'clock every morning, and the Atlantic Express at 17.15 every evening. The reason for this last strange-sounding time is that west of Winnipeg the trains run on a 24-hour time-table, where the distinctions between a.m. and p.m. have been dropped; 17.15 therefore corresponds to the more usual 5.15 p.m.

On June 1st, 1919, the transcontinental expresses were given a timing between Montreal and Vancouver of 93 hours 30 minutes west-bound and 92 hours 15 minutes east-bound. The best service in the United States takes more than 98 hours from New York to the Pacific Coast. But of course in this latter case there is no through connection, and two or three separate roads are involved.

The Canadian Pacific has not rested content with its great stretch of main line, 3078 miles long though it is from Quebec to Vancouver. In the east, long lines of railway have been either built or acquired, connecting Montreal with St. John in the Province of New Brunswick and with Monckton, where connection is made by means of the Inter-Colonial railway with Halifax, Nova Scotia, which forms a convenient Atlantic winter port. Another line has been pushed up the St. Lawrence Valley as far as Toronto and Detroit, where connection is made with the Wabash Railroad for Chicago. Further west still, the Canadian Pacific also controls the Duluth, South Shore and Atlantic Railway, which stretches from Duluth along the southern shore of Lake Superior to a connection with the main line at Sault Sainte Marie. Beside this it also controls the extensive mileage of the Minneapolis, St. Paul and Sault Sainte Marie Railway, which connects with its own main line at Winnipeg and other points further west. In the great western provinces of Manitoba, Assiniboia, Saskatchewan and Alberta it is also busily engaged in continually adding new mileage to its already extensive system.

Nor is this all; not even the possession of over 12,000 miles of rail has sufficed for the untiring enterprise of this great Company. In its early days it soon started in business as a steamship owner by running a line of steamers across the great lakes between Owen Sound on Georgian Bay, Lake Huron, and Fort William at the north-western end of Lake Superior, a distance of 555 miles. These steamers of course are laid up during the winter months, as navigation is impossible because of ice, but during the summer-time they form a pleasant alternative route for passengers between east and west. The next step as a ship-owner was taken when the railway built its three 6000-ton "Empresses"



Westwood to the Far East: The Newest Canadian Pacific Express Engine.

for service across the Pacific between Vancouver, Yokohama, and Hong Kong.

Then came the Klondyke gold rush, when the Company's steamship line was extended along the Pacific Coast to the mouth of the Yukon River, and, not content with all this, the Canadian Pacific house flag is now flying on the stormy North Atlantic. Its steamers and trains now afford a service extending from Liverpool to Hong Kong, a distance of more than 11,900 miles.

This is the line to which the splendid specimen of locomotive engineering which is represented in our picture belongs; No. 1100 represents the extreme development of the express passenger engine in the type which we have already learned to call the "Pacific." Though considerably smaller than the immense engine of this class for the Pennsylvania Lines, which will be described later, Mr. Horsey's machine is a strikingly handsome one, and well worthy of being put on record as an example of Canadian locomotive building. The boiler is of a modified wagon-top type, in general outline somewhat suggesting the pattern which Mr. Churchward has adopted as the standard for the Great Western Railway. This boiler is 5 ft. 6 in. in diameter at its smallest part, and has 193 tubes each 2¼ in. in diameter and 22 tubes 5 in. in diameter, all being 19 ft. 6 in. long between the firebox and smokebox tube plates. These tubes afford a total heating surface of 2777 square feet. The firebox is of semi-wide type with a grate area of 45·6 square feet, and contributing another 180 square feet to the total heating surface, which thus amounts to 2957 square feet. Like several other recent locomotives for this line, No. 1100 is fitted with a superheater. The general principles of superheater working I have already touched upon in describing the new London and North-Western engines. The working pressure of the boilers of these engines is 200 lb. per sq. in.; this boiler supplies steam by means of piston valves to a pair of simple cylinders 21 in. in diameter with a stroke of 28 in. The driving wheels measure 6 ft. 3 in. in diameter, the wheels of the leading bogie 2 ft. 10 in., and the trailers 3 ft. 9 in. The total weight of the engine in running order is 94 tons 12 cwt., of which 62 tons 1 cwt. is carried on the drivers. This means a running weight of more than 20 tons on each driving axle, an eloquent testimony to the substantial nature of the Canadian Pacific track. The tender, loaded, weighs 54 tons 15 cwt., the total weight of engine and tender being thus 194 tons 7 cwt.

An interesting feature of this engine is the electric head-light. The electricity is generated by means of a small dynamo mounted on the extended smokebox immediately in front of the chimney. The valve-gear of this engine is of the old-fashioned Stephenson link type. This gives the engine an appearance of straightforwardness and simplicity which is curiously at variance with the look imparted to most modern American engines by the more involved types of gear, such as the Walschaert, now being so largely introduced.

These new engines are used principally on the main lines east of Lake Huron and Lake Superior. Under the special condition of working of which No. 1100's head-light speaks to us, it is, of course, vain to look for high booked speeds. The Montreal and Chicago express, for example, which leaves the Windsor Street station of the former city at 10 p.m. every evening, averages 35·89 miles per hour to Toronto, a distance of 338 miles. Leaving Toronto at 8 the following morning the train is handed over the Wabash at Detroit, 231 miles further on, at 3.10 p.m., the average speed from Toronto to Detroit being only 32·23. As a set-off to this it must be remembered that this train, though called an express, is booked to stop at nearly every station, that the line for the most part is single and the train is not particularly light. The standard of locomotive work involved, therefore, is considerably higher than would appear from a mere record of the average start to top speed.

As an interesting instance of mountain timing we may notice the run, or rather climb, from Beaver Mouth to Roger's Pass, 21 miles in 1 hour and 56 minutes. This gives an average speed for the Imperial Limited over this section of a shade over 11 miles an hour. The explanation of this timing is that in this 21 miles the line clambers 1775 ft. up the precipices of the mighty Selkirks. Here occur the great snow-sheds massively built of timber bolted to the rock and extending for miles along the most exposed portion of the Pass. The tracks through these snow-sheds are only used in the winter time, there being an outside track for summer use. Not even our big "Pacific" can take the Limited over a division like this, where the road rises 116 ft. to the mile. The train has to be entrusted to three powerful consolidation engines, two pulling and one pushing behind. These engines have 8-coupled driving wheels with a 2-wheeled leading pony truck, and, powerful as they are, the heavy Limited taxes their hauling capacity to the uttermost.

The railway is now boring what will be the longest tunnel on the American Continent, in order to avoid the worst part of this grade. It will be 5½ miles in length, double track throughout, and will be operated by electricity. When it is in use the length of the main line will be shortened by 6 miles and the gradient considerably reduced.

We have now gained some idea of the great road to which the engine here pictured belongs, and I think we shall feel that the Canadian Pacific Railway, both in its inception and in its every-day working, represents one of the greatest human triumphs over natural difficulties and dangers. Its future fortunes are intimately bound up with those of the great nation whose name it bears, and the development of both the nation and the railroad seems to be one of the great projects of this twentieth century of ours.

BURMA RAILWAYS

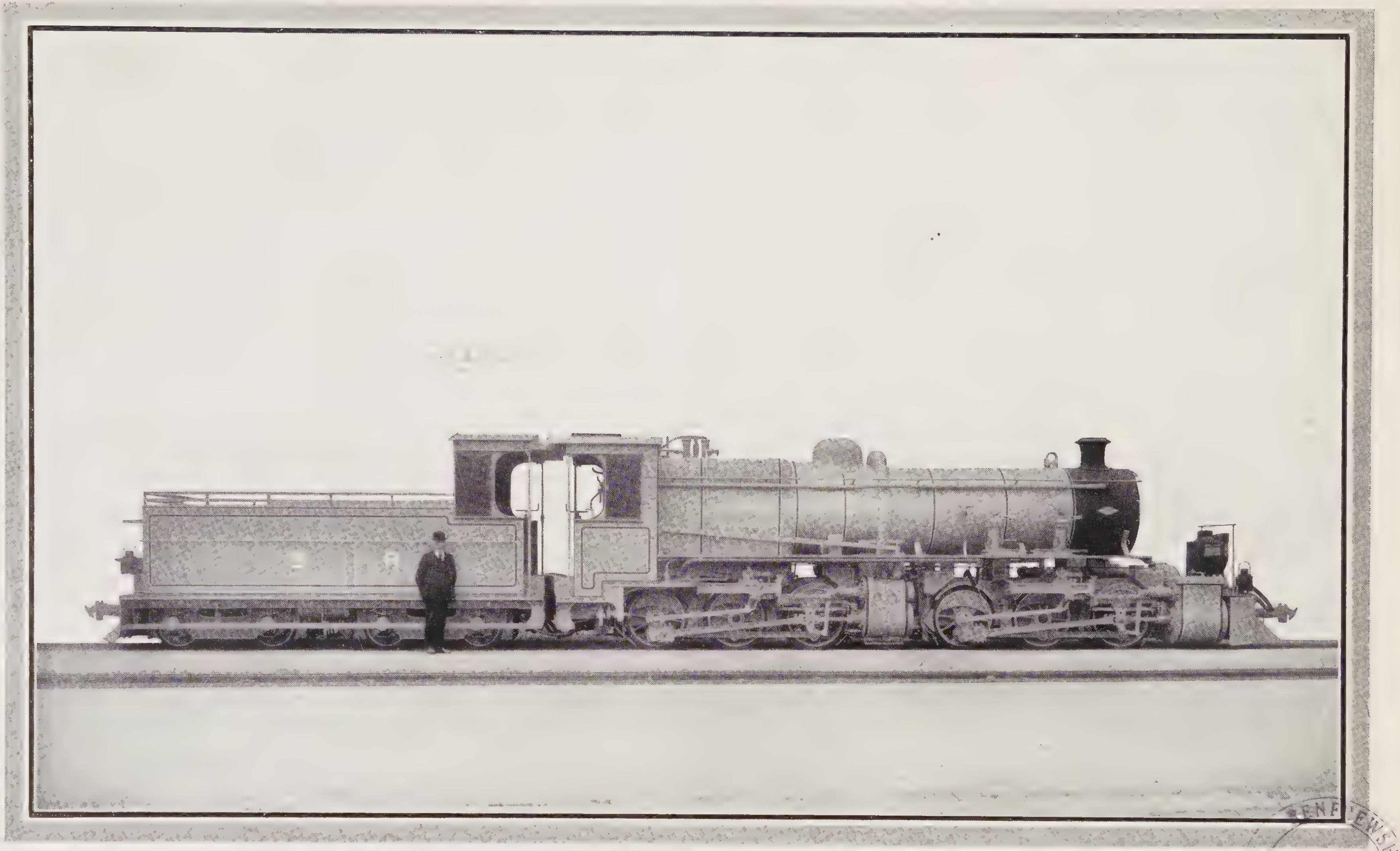
Burma lies on the eastern shores of the Bay of Bengal, Rangoon (the capital) being situated near the 17th parallel of North Latitude. From Rangoon to Mandalay the country falls within the limits of the Tropics. Burma has a topical situation and climate, and its rainfall amounts in places to no less than 190 inches a year. The low-lying lands forming the delta of the great Irawaddy are humid and fertile, and still covered mostly by jungle. Perhaps the most famous hardwood in the world is the celebrated Moulmein teak. There are few of the railways of the world that do not use it for their carriage stock. The riches of the land are hardly explored yet, but its soil is known to be extraordinarily fertile; and its mountains away up in the north are more than suspected of being rich in coal, tin, and many other valuable minerals.

Little is known of Burma before the eighteenth century. Records of an earlier time, which are so abundant in the case of its great neighbours, India and China, are as yet entirely lacking. Nor does it seem likely that they will now be forthcoming. In 1795 Great Britain came into direct contact with Burma over a quarrel that arose with its powerful emperor Alompra. Endless disputes punctuated the course of the next ninety years, and at length in 1886 the whole of the country was formally annexed by Great Britain. While political events were pursuing this chequered course, the early part of the nineteenth century was made memorable by the heroic labours and suffering of Adoniram Judson, the great American missionary. He was imprisoned by King Theebaw in Mandalay. On Theebaw's accession to the throne a massacre of 600 people took place as a kind of blood-offering to ensure the success of his reign; and when the city of Mandalay was built, fifty-six young girls were slain in order that their blood might be mixed with the cement at the thresholds of the eight gates of the city. It was supposed that such a sacrifice would render the city immune from capture.

After the annexation, a new experience began for the British officers responsible for the conduct of affairs, and with the new experience a new word passed into our ever-growing English language—the word *dacoit*. For twenty years the conflict with its robber bands dragged on, and many British officers laid down their lives. In the end, an effective police force was created and the *Pax Britannica* came to have a real meaning for turbulent, cruel Burma.

One important agent in the pacification and civilization of the country has been, of course, the railway. Construction began in 1887, and has gone on steadily, though slowly, ever since. The main line now extends from Rangoon northward through the Sittaung Valley to Mandalay and thence to Myitkyina. Mandalay is 386 miles from Rangoon, and Myitkyina 724 miles. The distance is not yet continuous, however, for near Mandalay the great Irawaddy has to be crossed. The line runs down to Amarapura shore, five miles out of Mandalay; thence the ferry steamers go two miles across to Sogaing, which the Railway Department reckons as 393 miles from Rangoon. This main line is stretching out towards China, as a glance at the map will show; and some day a new and fairly convenient through route will be opened up over the Burma Railways to South China. But that is not yet. Other important lines radiate from Rangoon, which also has one or two suburban branches giving a very efficient local service. These secondary main lines reach to Marteban, 168 miles to the south-east; to Prome, 161 miles north; and to Bassein, 192 miles away in the Irawaddy delta in the south-west. In this last case the river has again to be crossed by a ferry located at Henzada.

Coming back now to the main line, it is of interest to note some of the timings. It will be observed that the Burma Railways use the 24-hours time. The Mandalay mail leaves Rangoon at the hour of 18, or in other words 6 p.m. Mandalay is reached at 14.5, which gives 20 hours 5 minutes for the 386 miles, a running average, including stops, of a little less than 20 miles per hour. The Sogaing ferry takes 35 minutes. Myitkyina is reached at 16.50 the second day after leaving Rangoon. The total time for the trip is thus 46 hours 15 minutes, or an average speed of just under 16 miles per hour including everything. The line is of metre gauge (about 3′ 2″) throughout, and of course grades are severe. The locomotive stock reflects the physical characteristics of the country. Fairlie-type engines have been used to some extent. The standard express locomotives are of the 4–6–0 type, and there are also some very smart little 2–6–2 tank-engines for the Rangoon local services.



"On the Road to Mandalay":
"Mallet" Type Engine for the Burma Railways.

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The increasing traffic, however, and the very heavy nature of the country have made the provision of increased locomotive power necessary, and the Mallet Compound has been deemed a suitable type for the special circumstances of the Burma Railways. In this class of engine it is easy to provide adequate power combined with extreme flexibility of wheel base. The Mallet is not suitable for fast traffic, but where the booked speeds are low, as in Burma, they answer admirably. [These handsome locomotives have all been built by the North British Locomotive Co., to whom I am indebted for the photograph and details.] The wheels are 3′ 3″ in diameter. The high-pressure cylinders drive the rear group of coupled wheels, as is usually the case in a Mallet. They are 15½″ in diameter with a 20″ stroke. The low-pressure cylinders have a diameter of 24¼, the stroke being the same as the high-pressure. The distribution of steam in the high-pressure cylinders is controlled by piston valves, while those for the low-pressure cylinders are of the usual flat D pattern. In both alike the valves are actuated by Walschaert gear. The total rigid wheel base of the engine is only 8′ 3″, thanks to the use of the Mallet system. The boiler has a Belpaire firebox, with a grate area of 33 sq. ft. and a heating surface of 115 sq. ft. The tube heating surface is 1437 sq. ft., giving a total of 1552. The working pressure is 180 lb. Such is a specimen of British workmanship exhibited in one of the far-away corners of the Empire.

PENNSYLVANIA LINES

Under the above title is grouped together a number of roads lying in the extreme west of Pennsylvania and stretching out through the States of Ohio, Indiana, and Illinois, westward to the Mississippi, and through Michigan northward to Lake Michigan. The chief of these lines are the Pittsburgh Fort Wayne and Chicago Railway, the Cleveland and Pittsburgh, the Toledo Walhonding Valley and Ohio, the Pittsburgh Cincinnati Chicago and St. Louis, the Vandalia, and the Grand Rapids and Indiana Railroad. There are many other smaller lines included, and the total length of road operated in this way is more than 4700 miles. All these Pennsylvania Lines are of course directly under the control of the Pennsylvania Railroad, working through the subsidiary organization known as the Pennsylvania Company. Besides this there are a good many other little lines which the Pennsylvania controls through purchase of their stock or bonds, but which are yet worked by their own organizations.

The total length of road included under the vast ramifications of this great company measures over 10,500 miles, and the President of the Pennsylvania Railroad has a position of power and responsibility which is truly kingly. The seat of his government is at Philadelphia, and the territory over which he rules stretches from Montauk, near the the extreme north-eastern point of Long Island, as far as St. Louis on the west bank of the Mississippi, a distance, as the crow flies, of about one thousand miles. We may describe his rule, in the terms of our geography books, as bounded on the east by the Atlantic, on the north by the great lakes, on the west by Chicago and the Mississippi, and on the south by the rivers Ohio and Delaware.

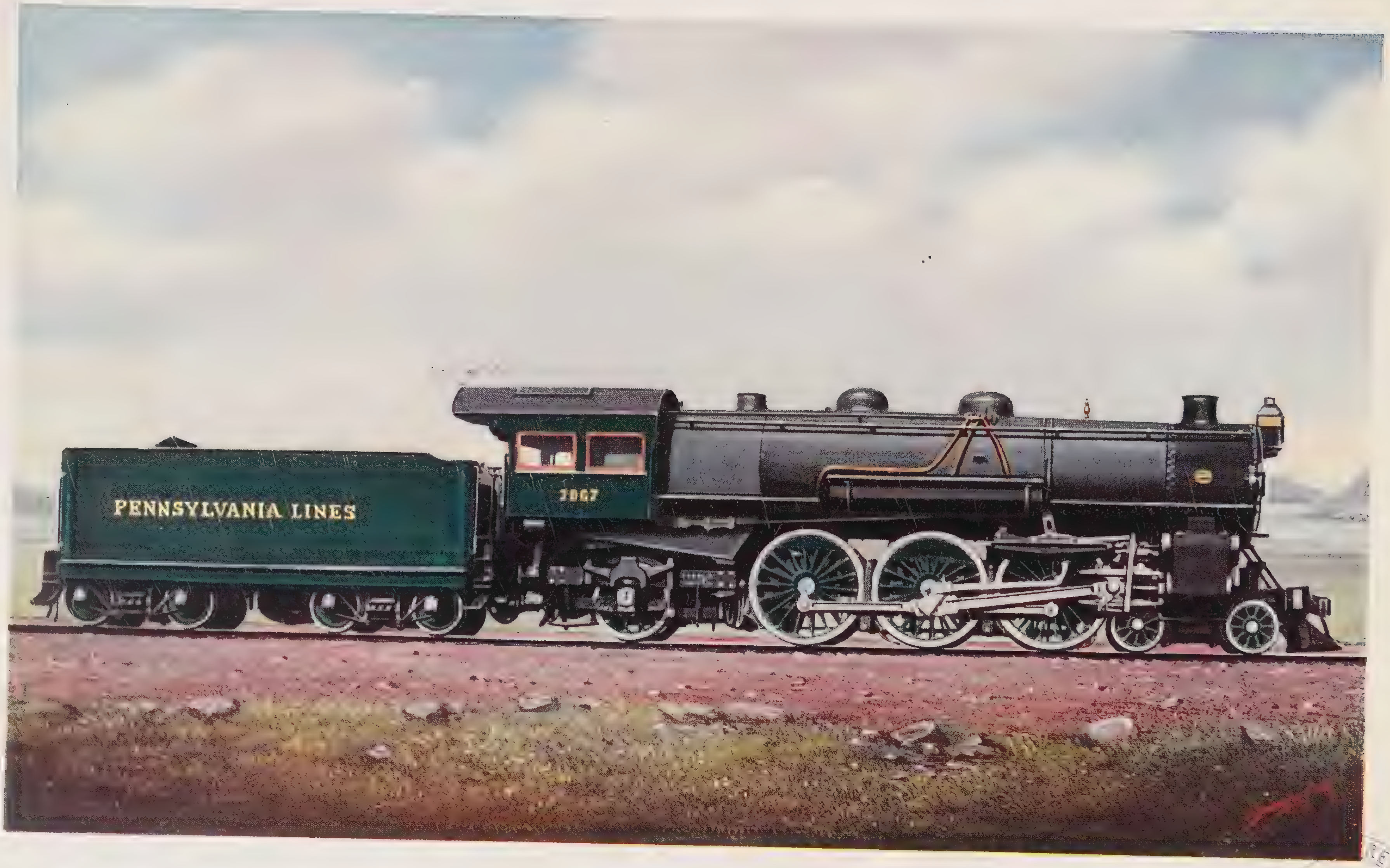
The most important train services are those connecting New York (Jersey City) and Philadelphia in the east, with Pittsburgh, Chicago, Columbus, Burlington, Indianapolis, Terre Haute, St. Louis and Cincinnati in the west. In spite of the wide-flung branches of this great system, nearly half the mileage lies among the mountains of the State of Pennsylvania. Little branch lines creep up all sorts of out-of-the-way gullies and ravines of the great Alleghanies, for the hills are rich in minerals, and in one year recently the road handled 12,000,000 tons of coal and ore. Many of these little lines are used for mineral traffic only; others have perhaps a passenger train weekly or daily. In all, the Pennsylvania finds work for about 7000 locomotives, of which I suppose about 1700 are used for passenger work, the remainder being freight and switching engines.

The company's shops are at Altoona, in the heart of the mountains, and 1180 feet above sea level. The summit of the main line is between ten and eleven miles west—or rather north-west—of Altoona, and situated in Gallitzin Tunnel. In these last ten miles the line climbs another 1000 ft. among most romantic and beautiful scenery. The wide four-track way crawls around ledges cut in the hill-sides, crossing valleys on high embankments and twisting in and out wherever it can find foothold until it comes to the great horse-shoe curve at Kitanning Point. Further on three tracks climb to the summit tunnel, through which at present two tracks lead.

Altoona is the Crewe of America, and the Pennsylvania shops are more self-contained than any others in the United States. Most American lines have their locomotives and cars built by outside firms, but the Pennsylvania build nearly all their own. They also roll their own rails, almost the only railway in the world, except the London and North-Western, which does this, and they have recently added to their activities a forestry department, which is to supply all the lumber required for ties or sleepers, as they are termed in England.

The new private shops are probably the finest in the world. They are, of course, planned upon the most economic and scientific principles, and designed to prevent all unnecessary moving about of materials. The shops are large and excellently lighted, manual labour is reduced to the lowest possible minimum by labour-saving appliances, and compressed air-tools are installed everywhere. In spite of all this labour-saving, there are 7000 men on the pay-rolls, and for their comfort the most careful provision has been made in the shape of lavatories, cloak-rooms and dining-rooms. As in some of our big railway works, flowers and shrubs have been introduced where possible, so the Juniata shops stand amid beautifully-laid-out gardens with smooth lawns, beautiful flower-beds and well-kept walks.

It is quite in accord with the fitness of things that this splendid railroad should have the prestige of building and running the biggest



The "Pacific" in its Native Land: The Newest Express Locomotive for the Pennsylvania Lines.

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passenger engines in the world. Such are the huge locomotives of which No. 7067 is an example. Like the Canadian engine already illustrated she is a "Pacific," but this Pennsylvania engine is, at the moment of writing, quite the biggest engine of the type in the world.

This class of engine is really a combination of two others, of which several examples are included in these pages, the "Atlantic" and the ten-wheeler. Like the former, the "Pacific" type has a leading four-wheeled bogie and a pair of trailing carrying-wheels under the firebox: like the latter the "Pacific" is a six-wheels-coupled engine. There is thus a combination of the distinctive excellences of the two types. The "Atlantic" type presents an easy-running engine with a flexible wheel base, and also allows room for the provision of a large firebox. On the other hand, the power which it can actually make use of is not more than an eight-wheeled engine can use, because in both cases the adhesive weight will be about the same, carried as it is upon two pairs of coupled wheels.

The ten-wheeler, on the other hand, supplies the extra tractive force utilized through three pairs of drivers instead of two, but the third large pair of driving wheels, coming at the rear end of the engine, somewhat cramps the firebox and reduces the resultant grate area and heating surface available. To get over this difficulty engines have been built of what is known as the "Prairie" type. In this class of engines the leading four-wheeled truck has been virtually divided, a two-wheeled pony truck being left under the leading end and another two-wheeled truck added underneath the firebox. In our present "Pacific" type we have reverted to the four-wheeled leading bogie.

The engine before us is a giant even in the land of giants. A few years ago, in the *Boy's Book of Locomotives*, I had to describe a "Prairie" with 3905 sq. ft. of heating surface, for the Lake Shore and Michigan Southern Railroad, as, at the moment of writing, the biggest passenger locomotive in the world. In the same year the first engine of the class we are now considering came out with 4427 sq. ft. of heating surface, a monster indeed, whose supremacy down to the present moment is unchallenged. The dimensions even of our "Pacific" have been, however, exceeded by the Mallet Compounds, which have been built for the Atchison Topeka and Santa Fé Railroad at the Baldwin Works, Philadelphia. Mr. Ely, the Pennsylvania's Chief of Motive Power, in common with other leading American engineers, has for years been an advocate of ample boiler power, a factor in locomotive design which is to-day universally recognized as the finally determining one.

This present engine is thus no exception to his rule, the boiler power being fully equal to the demands of the 24″ × 26″ cylinders. The cylinders present 5·31 cubic inches of volume for every square foot of heating-surface. This approximates very closely to the 5·2 cubic inches of the big Lake Shore engine, and shows a considerable reduction as compared with the 7·4 cubic inches of Mr. Ely's own "Atlantics" of two or three years ago. The great area of the firebox amounts to 61·8 sq. feet.

As the reader will see from our picture, the steam distribution is effected by means of piston valves controlled by Walschaert's gear. These piston valves are 16″ in diameter. The rapid growth of the Walschaert gear in the favour of American engineers is very remarkable. I have several times in this book pointed out the filtering of ideas eastward across the Atlantic; in this case we have to record an invention which, like the original locomotive itself, has travelled westward. The gear is carried, as will be seen from the picture, on an auxiliary framing, attached to the main frames just above the leading drivers.

The driving wheels are 6′ 8″ in diameter, while the boiler measures 6′ 7¾″ in diameter by 21 feet long. The working pressure is 205 lb. per sq. inch. The weight of the engine in running order is 123·25 tons, and of the tender, with 11 tons of coal on board, 62·5 tons; the total weight of engine and tender amounting thus to 185·75 tons. The large cylinder which appears just under the bulge of the boiler is the compressed air reservoir for working the Westinghouse brake. Ample storage capacity for air supply is needful with heavy trains working over hilly roads. The Pennsylvania's splendid example of American design is intended to haul trains weighing as much as four or five hundred tons behind the tender at high speed. There are a good many fast ordinary and limited expresses working over the Pennsylvania tracks. The pride of the road is the great 18-hour New York–Chicago special, which is booked at almost exactly 50 miles an hour throughout, stops included, all the 906 miles between Atlantic tidewater and the inland sea of Lake Michigan. It is in work such as this that Mr. Ely's big engines are called upon to take their part.

SOROCABANA RAILWAY

Brazil is a vast country with nearly three and a quarter million square miles of territory; but its railway system is still very little developed. The principal centres from which the lines radiate so far are Rio de Janeiro and São Paulo. These cities are 498 kilometres apart, or about 317 miles, which is, roughly, the distance from Euston to the Scottish Border. The time occupied in transit is 13 hours 5 minutes, and the journey speed over the Brazil Central Railway 24·5 miles an hour. This is one of the few broad-gauge lines in Brazil, the tracks being laid to a gauge of 1·60 metres, or very nearly 5′ 3″.

Most of the Brazilian roads, however, are metre gauge, which is just over 3′ 3″ English measure. Among these is the Estrado de Ferro Sorocabana, for which the locomotive illustrated has been built. This line runs from São Paulo in a general westerly and south-westerly direction. It has four chief western termini at São Pedro, Bauru, Guarucaia and Itarare respectively.

The first of these is connected by a branch of the Sorocabana with Jundiahy, where there is a junction with the São Paulo Railway, affording much the shortest route to that city. At Itacy the line crosses the Sorocabana's own branch running from São Roque to Campinas. São Pedro is 120 miles from Jundiahy, which is 37½ miles by the São Paulo line from that city.

The Sorocabana derives its name from the town of Sorocaba, through which passes its main line, afterwards branching out in widely different directions to reach the remaining three termini. Of these, the northernmost is at Bauru, where connection is made with the North-Eastern Railway of Brazil. This point is 439 kilometres, or 275 miles, from Sao Paulo. The sleeping-car train leaves the latter place at 20.05, and arrives at Bauru at 10.34. The time on the journey is 14 hours 29 minutes, and the journey speed 19 miles an hour.

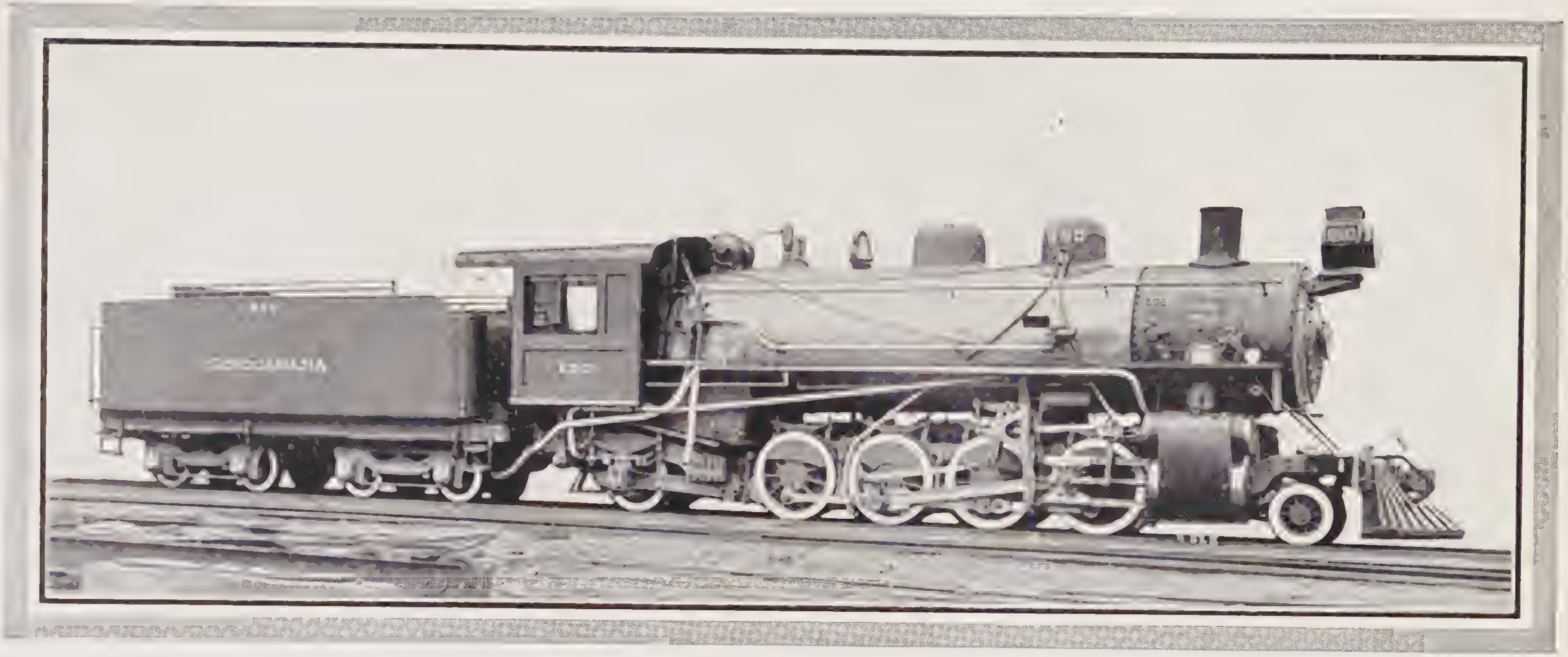
The longest section of the railway is the one next in geographical order; it terminates at Guarucaia—at least, that is as far as it has reached at present—but it is stretching out, and will eventually come to the banks of the mighty Parana. So far, it has reached a distance of 515 miles from São Paulo. The journey takes exactly 29 hours, but that includes 10½ hours allowed for a night's rest at Indiana.

The last division of the line to be mentioned is really the most important of them all. It leaves the west-bound line at Boituva, 101 miles out from São Paulo, and runs south-westward to Itarare. Over this section passes the international route, which now gives through railroad connection from Rio to Monte Video. This is a distance of just 2000 miles, but the through travelling is of course spoiled by the break of gauge to which I have already referred. The time table of this international service may be thus summarized :—

STATION	DISTANCE		RAILWAY	TIME	DAY
	KILOMETRES	MILES			
Rio de Janeiro			Brazil Central	dep. 7	Wednesday
Sao Paulo	498	311		arr. 18.16	"
Sao Paulo			Sorocabana	dep. 20.05	"
Itarare	932	582		arr. 10.07	Thursday
Itarare			Rio Grande	dep. 10.30	"
Marcellino Ramos	1818	1136		arr. 20.30	Friday
Marcellino Ramos			Rio Grande do Sul	dep. 21.20	"
Sant' Ana	2633	1642		arr. 7.50	Sunday
Rivera			Uruguay	dep. 11.30	"
Monte Video	3200	2000		arr. 7.05	Monday
Monte Video			By steamer	dep. 22	"
Buenos Aires				arr. 7	Tuesday

Sant' Ana and Rivera stand on opposite banks of the Cuarein River. There is no physical connection between the railways on the two sides, and passengers have to change and cross by ferry. From Rio to São Paulo and from São Paulo to Santa Maria, 280 kilometres north of Sant' Ana, restaurant cars are run, as well as between Rivera and Monte Video. Through sleeping cars are run from São Paulo to Sant' Ana, and also from Pampa, about 200 kilometres south of the last-mentioned place, to Monte Video. The steamer connection at Monte Video is very bad, involving practically a whole day's wait at that point. Then there is a nine-hours' trip across the magnificent Plate estuary to Buenos Aires. It will therefore be seen that the Sorocabana Railway forms an essential link in the great chain of connection which is gradually being perfected between the north and the south.

The railroad belongs to an American corporation whose head offices are at Portland (Maine). It is therefore natural that its rolling-stock



Through Brazilian Forests:
Wood-burning "Mikado" Type Engine for the Sorocabana Railway

should be American. The engine illustrated was built by the American Locomotive Co. It is of the "Mikado" type with a wheel arrangement represented by the formula 2-8-2. The driving wheels are 3′ 5$\frac{3}{4}$″ in diameter. Steam is supplied by a boiler having an inside diameter of 5′ 1″, with a heating surface of 1455 sq. ft. The firebox supplies an additional 102 sq. ft., making a total of 1557 sq. ft.; while the superheating surface is 383 sq. ft. The firebox measures 6′ 0$\frac{3}{16}$″ long by 5′ 0$\frac{1}{4}$″ wide, and has a grate area of 30·2 sq. ft. It is arranged for burning wood. The cylinders are simple, having a stroke of 20″ with diameter of 19″. Steam is admitted through piston valves controlled by Walschaert gear. Altogether No. 650 looks a well-proportioned and workmanlike engine for trying service on what is almost a pioneer road.

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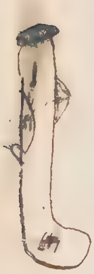

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